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ON THE CAUSE OF THE DIURNAL OSCILLATION OF THE BAROMETER.

BY ROBERT LAWSON, LL.D., Inspector-General of Hospitals.

(Communicated by R. H. SCOTT, F.R.S., F.R.Met.Soc.)

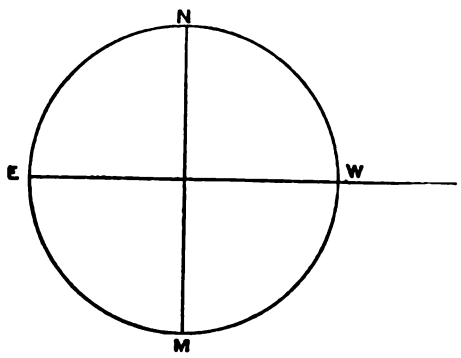
[Read November 16th, 1887.]

IN attempting to account for the diurnal oscillation of the barometer, meteorologists have hitherto confined themselves to the effects of temperature and moisture; these agencies exercise during the day considerable influence on its course, but during the night, when they are to a large extent in abeyance, something else is required to give rise to the fluctuations which then occur. The object of the following remarks is to indicate another factor, which is constantly in operation during the night as well as the day, and upon which the generality and regularity of the oscillation mainly depend.

Let it be assumed that a sphere is suspended in space, without motion, and that it is surrounded by an atmosphere which is not subject to disturbance from temperature, or from any external influence; the atmosphere will envelope the sphere in a coating of uniform thickness. If now a rotatory motion be given to the sphere, owing to the centrifugal action at the Equator counteracting that of gravity to some extent, the surrounding atmosphere will acquire a greater thickness there than at the poles, but otherwise it will soon take on

the same amount of motion as the surface of the sphere on which it rests, and will rotate with it without any current or disturbance. When this state of equilibrium has been attained, if a progressive or orbital motion be added the following changes are introduced, which will be made clearer by the accompanying diagram.

Let N E M W represent the plane of the Equator of the sphere, which rotates in the same direction, and let the orbital motion be in the line EW produced; then it is obvious that a point on the surface of the sphere, in moving from E through M to W during a half revolution, will have a motion in the direction of that of the orbit greater than the advance of the centre of the sphere by its diameter, and in the following half revolution, WNE, there will be a motion of the same amount, but opposed to the orbital motion; and it is these alternate accelerations and retardations, as regards the motion of the centre of the sphere, that are mainly concerned in causing the fluctuations of the atmosphere on its surface which produce the diurnal oscillation of the barometer.



To acquire an adequate knowledge of the time of occurrence, and amount of the diurnal atmospheric fluctuations, it is necessary to have recourse to observations made at some point near the Equator, close to the sea-level, and as far removed from any considerable mass of land as possible. The only series I am aware of, which fulfils these conditions fairly, is that made by Lieut. Rokeby, Royal Marines, at Ascension, from September 1863 to August 1865. These were discussed at the Meteorological Office, and I am indebted for a copy of the paper to the Secretary of that Office. Ascension is a small and mostly low flat island, 825 geographical miles from Cape Palmas, the nearest point of the African Continent, and about 1,200 miles from that of South America. The observations were made on the North-west of the Island, in lat. 7°55′ S, long. 14°25′ W, and 53 feet above the sea-level.

The first question to be determined in investigating this subject is the space which a point at the Earth's Equator passes through in a short period, such as a second of solar time. Taking the Earth's equatorial diameter at 7925·8 English miles, the length of an arc of 15″ there will be 1521·644 feet; but as the solar day exceeds the complete circle by $\frac{1}{365}$th part, that

fraction must be added, making the space covered, for 1 second of solar time, 1525·813 feet at the Equator; but at Ascension, being reduced in the proportion of the cosine of 7°55′, this becomes 1511·271. As the Equator forms an angle of 28°27′ with the plane of the orbit, and as for this inquiry motions parallel to the former have to be reduced to what they would be on the latter, this number has to undergo further alterations according to the periods for which it is employed; thus at the equinoxes, when the line of section of the plane of the equator with that of the orbit is at right angles with a tangent to the orbit, the correction would be for an angle of 28°27′, while at the solstices, where it coincides with the tangent to the orbit, the correction vanishes. In dealing with a year, only, a mean of these extremes with the intermediate numbers can be obtained, but for single months a closer approximation can be made. For the year, taking the sun's declination every fifth day, and dividing their sum by their number 78, a mean declination of 14°47′ is obtained; this corresponds with a point on the Equator 87°28′ from the intersection of the planes of the Equator and the orbit, and with a point on the latter 39°52′ from the line of intersection; a plane perpendicular to that of the orbit, passing through 39°52′ and the Earth's centre, will cut the plane of the Equator at an angle of 15°32′ to that of the orbit, and the space passed over in one second in the latitude of Ascension, given above, has to be reduced in the proportion of the cosine of this angle, and becomes 1456·071 feet. For the present purpose this quantity has to be resolved into two components, one acting in the direction EW and the other in that of MC, in the night half of the revolution, and in the opposite direction in the day half, and taking 1456·071 feet as the chord of an arc of 15″, and as radius, the sines at the various hour angles will give the component in the direction EW. In the following table the rate of advance per second of mean solar time is the mean of the second immediately preceding and that immediately following the hour angle, and the difference between these two shows the amount of acceleration or retardation between successive seconds at that point of the circle: the figures for 6 p.m. and 6 a.m. are the means for the first and second seconds after these hours.

Hour.	Angle from 6 p.m.	Advance per second of Solar Time.	Difference between successive seconds.	Hour.	Angle from 6 a.m.	Retardation per second of Solar Time.	Difference between successive seconds.
	°	Feet.	Feet.		°	Feet.	Feet.
6 p.m.	0	·106	·106	6 a.m.	0	·106	·106
7 ,,	15	376·859	·102	7 ,,	15	376·859	·102
8 ,,	30	728·036	·092	8 ,,	30	728·036	·092
9 ,,	45	1029·599	·075	9 ,,	45	1029·599	·075
10 ,,	60	1260·995	·052	10 ,,	60	1260·995	·052
11 ,,	75	1406·458	·027	11 ,,	75	1406·458	·027
Midnt.	90	1456·071	·000	Noon	90	1456·071	·000
1 a.m.	105	1406·458	·027	1 p.m.	105	1406·458	·027
2 ,,	120	1260·995	·052	2 ,,	120	1260·995	·052
3 ,,	135	1029·599	·075	3 ,,	135	1029·599	·075
4 ,,	150	728·036	·092	4 ,,	150	728·036	·092
5 ,,	165	376·859	·102	5 ,,	165	376·859	·102

It will be observed, from the figures in this table, that the motion in advance of a point in the latitude of Ascension, when reduced to the plane of the Earth's orbit, increases rapidly from zero at 6 p.m. to its full amount at midnight, and the difference in the rate between two successive seconds diminishes over the same period. From midnight to 6 a.m. the motions in advance decrease in reverse order, while the differences between successive seconds increase. Similar movements occur from 6 a.m. to 6 p.m., only in place of being in the same direction as the orbital motion they are opposed to it. It consequence of its rigidity a point on the Earth's surface continues to rotate with regularity notwithstanding these changes of motion, but the atmosphere surrounding it, from its mobility, requires time to take them on, and, when acquired, to part with them again; in the former case the air will lag behind the advance of the surface on which it rests, and gradually become more compressed, and in the latter it will advance faster than the surface, and tend to fly off centrifugally, leading to a decrease of pressure. Thus at 9 p.m. while the advance during the previous second is 1029·561 feet and that during the following one 1029·636 feet, the difference between them, ·075 feet, is the additional motion required to be imparted to the air to carry it onwards at the same velocity as a point on the subjacent surface. At 3 a.m., again, the motion in advance in the preceding second is 1029·636 feet, and in the following one 1029·561 feet; the difference, ·075 feet, being in excess of the accompanying motion of the surface in the same direction, thus becomes a centrifugal factor, leading to a diminution of the pressure.

It may be asked here, Why, if the rise and fall of the barometer be due to these differences of motion, the maximum does not occur about midnight, and the minimum about 6 a.m., instead of at 10.16 p.m. and 3.26 a.m. respectively, as is actually the case? This is due to the action of gravity, which, though a constant quantity acting directly towards the Earth's centre, may be resolved into two components operating at right angles to each other, and each varying from unity to zero as it passes through the different hour angles of each quarter at the revolution. Referring to the diagram given above, and using the angles of the centre for the different hours, in the quadrant EM the sines will represent the component of Gravity acting in the direction MC, and the cosines that in the direction EC; in the quadrant MW the sines are still in the direction MC, but the cosines are in that of WC, or opposite to those in the preceding quadrant. In the quadrants WN and NE the components act similarly to those in EM and MW respectively, but in the opposite directions.

Assuming Gravity in the plane of the Equator = 1, that at Ascension acting parallel to it would be ·9905, and if the latter be further corrected for the angle the Equator forms with the plane of the orbit 15°32′ (as given above), it becomes ·9543. The former is the basis for the components MC and NC which are not affected by this angle, and the latter of those in the direction EC and WC, which are reduced to the plane of the orbit so as to be directly comparable with the differences between the successive seconds. The relative amounts of these components are as follows:—

Hour.	Angle at Centre from E.	Component in direction		Hour.	Angle at Centre from E.	Component in direction	
		MC.	EC.			MC.	WC.
	°				°		
6 p.m.	0	·0000	·9543	Midnt.	90	·9905	·0000
7 ,,	15	·2564	·9218	1 a.m.	105	·9567	·2470
8 ,,	30	·4952	·8264	2 ,,	120	·8587	·4771
9 ,,	45	·7004	·6748	3 ,,	135	·7004	·6748
10 ,,	60	·8578	·4771	4 ,,	150	·4952	·8264
11 ,,	75	·9567	·2470	5 ,,	165	·2564	·9218
Midnt.	90	·9905	·0000	6 ,,	180	·0000	·9543

The numbers in this table show that in the quadrant EM the component of Gravity acting in the direction EC is at its maximum at 6 p.m. and at zero at midnight, while the other component increases from zero to unity in the same period. The former acts in the same direction as the advance caused by the rotation of the Earth already pointed out, and like it with gradually reducing force; the latter increases from E to M, and its influence on the mass of air which has been gradually accumulating at 10h. 16m. p.m. (at Ascension on the mean of the year) balances the diminishing forces which led to that accumulation, and after this Gravity prevails and the barometer begins to fall. In the quadrant MW a centrifugal motion occurs, as already explained, leading to a diminution of pressure; up to 1h. 8m. a.m., the moment of the daily curve crossing the line of mean pressure, the diminution is favoured by the action of the component MC; the other, now acting in the direction WC, is in opposition to that due to the Earth's rotation, and as it increases gradually acquires sufficient force to balance the centrifugal action: this occurs at Ascension at 8h. 26m. a.m., and after passing this the barometer begins to rise.

The above has reference to the changes going on in the half circle EMW, representing the night period: in the other half WNE, corresponding with the day, the motions due to the Earth's rotation are opposed to the orbital motion, and the component of Gravity indicated by the cosine acts with the motion of rotation in aiding the rise of the curve of diurnal oscillation in the quadrant WN as it did in EM, and against the centrifugal motion in EN as it did in MW, the result is a maximum in the former and a minimum in the latter, as in the night period, but the position and character of these are materially modified by the alteration of temperature then occurring, as well as by another manifestation of Gravity to be noticed below.

The following table shows the mean time of the maxima and minima, and of the curve crossing the line of mean pressure, for the two years at Ascension, with the angles from E and W of these points respectively, also the advance or retardation of a point on the Earth's surface per second at each, and the difference between two consecutive seconds, + when increasing, − when decreasing.

From the facts in this table, it appears that the day maximum occurred 55 minutes earlier in the semi-revolution than the night one, and the rise above

Period.	Time.	Angle from 6 p.m. or 6 a.m.	Advance or Retardation per second, Solar Time.	Difference between successive seconds.	Barometer, nearest hour + or − Mean.
	h. m.	° ′	Feet.	Feet.	
Night Maximum	10 16 p.m.	64 0	1308·709	—·046	+·0264
,, Minimum	3 26 a.m.	141 30	906·426	+·082	—·0170
Day Maximum	9 21 ,,	50 15	1119·489	—·068	+·0319
,, Minimum	3 45 p.m.	146 15	808·950	+·089	—·0381
Pressure Increasing, p.m.	7 22	20 30	509·927	—·100	..
,, Decreasing, a.m.	1 8	107 0	1392·449	+·031	..
,, Increasing ,,	5 52	178 0	50·816	+·106	..
,, Decreasing, p.m.	0 26	96 30	1446·712	+·012	..

the mean exceeded that during the night by one-fifth. The day minimum occurred 19 minutes later than the night one, and its fall below the line of mean was two and a quarter times greater. Arranging the times above and below the mean pressure for the night and day periods, with the rise or fall in each, the following are obtained, which will give a clearer view of their exact relations.

		From Mean to Maximum or Minimum. h. m.	Rise or fall of Barometer.	From Max. or Min. to Mean. h. m.	Total Time. h.m.
Above mean pressure.	Night period... ...	2 54	+ ·0264	2 52	5 46
,,	Day period	3 29	+ ·0319	3 5	6 34
Below mean pressure.	Night period ...	2 18	− ·0170	2 26	4 44
,,	Day period	3 19	− ·0381	3 37	6 56

The earlier rise in the day period is partly due to the increase of temperature which then occurs. Air expands $\frac{1}{491}$th of its bulk for 1° Faht., and if a quantity of air were in a closed vessel, a barometer suspended in it standing at 30 ins. would rise to 30·061 ins. on its temperature being raised by a single degree; in the open air far the greater part of the force generated by this expansion is expended in causing the heated portion to ascend through the cooler strata above, but there is still a residuum of pressure at the ground which accelerates the rise of the barometer there, and which leads to the earlier maximum and greater pressure than is observed during the night period when this factor is not in operation. After the higher day maximum has been reached, the more rapid transference of the warm air from the ground upwards masks the influence of farther rotation, and the barometer actually begins to fall. The portion of the diurnal oscillation below the mean pressure in the night contrasts strongly with that during the day, both in the time occupied and in the amount of depression. During the night period the portion of the atmosphere subject to centrifugal action may be said to be in front of the advancing body, which closes up behind it, reducing the amount of the resulting depression, and shortening its duration; during the day period, on the contrary, the portion of atmosphere affected is behind the advancing body, which moves away from it, thus

counteracting Gravity to a considerable extent, increasing the amount of depression, and lengthening the interval between the curve crossing the line of mean pressure and the hour of minimum, and also prolonging that between this hour and its reaching the mean pressure again.

The fluctuation in the tension of vapour at Ascension seems to have very little influence on the diurnal oscillation of the barometer; during the warmer part of the day, on the average of the two years, the tension is below the mean, falling from −·002 in. at 9 a.m. to −·010 in. from 11 till 1, from which it gradually rises to +·002 in. at 5; at 6 p.m. there is a rise to +·004 in., which by 9 p.m. reaches ·008 in. and then declines to +·004 in. at 1 a.m.; from this until 5 the tension remains about the mean; at 6 it has become +·003 in.; at 7 +·004 in.; and at 8 +·002 in. only; after which it falls below the mean, and remains so during the day, as already described.

Taking the evening rise from 6 to 9 p.m., the increased tension of vapour would have added ·004 in. only to the pressure, while the rise of the barometer in the same period was ·041 in.

The preceding examination has been confined to the yearly period, but it may now be shown that single months present the same general characters, though modified to some extent by the existing circumstances. To illustrate this, the months of June and December have been selected as indicating the condition at the solstices, and March and September those at the equinoxes, the extremes of deviation which occur. As the observations are given for months only, and the equinox or solstice does not occur exactly in the middle of the period, the tangent to the orbit for the middle of the month, viz. midnight on the 15-16th in June and September, and midday on 16th in December and March, was taken as the mean direction of the orbital motion for the month, and the angle at which a plane passing through this, and perpendicular to that of the orbit, cuts the plane of the Equator, was assumed as applicable to the whole month. The mean positions for the two years of the point from which the tangent was drawn in the different months, and the resulting angles in the plane of the Equator to that of the orbit were

	Tangent to	Inclination of plane of Equator to that of Orbit.
March 16th	357° 7′	23° 22′
June 15th-16th	84° 51′	2° 14′
September 15th-16th ...	173° 56′	23° 20′
December 16th	264° 33′	2° 22′

The space passed over at Ascension in a second of solar time has already been mentioned as 1511·271 feet; this reduced in the ratio of the cosines of the above angles of inclination gives 1387·325 for March and 1387·673 for September, and 1510·123 and 1509·782 respectively for June and December. These numbers for the two periods differ so little, that the mean 1387·498 feet may be taken to be the motion of a point in lat. 7°55′ S when

reduced to the plane of the orbit in the months of March and September, and 1510·053 in June and December.

In the original discussion of Lieut. Rokeby's observations the hours of maxima and minima of the barometer, in the different months in each year, were worked out by a formula employed by Dr. C. Jelinek, and are given in mean time; as they are more closely dependent on apparent time, however, they have been reduced to that here by applying the mean equation for the month with the proper sign; and the means of the two years so corrected are given in the following table, with the corresponding angles from 6 p.m. and 6 a.m. The times of mean pressure are also given with the corresponding angles.

Subject.	March.		June.		September.		December.	
	Hour.	Angle.	Hour.	Angle.	Hour.	Angle.	Hour.	Angle.
	h. m.	° ′	h. m.	° ′	h. m.	° ′	h. m.	° ′
Night Maximum	10 13	63 15	10 30	67 30	10 15	63 45	10 11	62 45
„ Minimum	3 6	136 30	3 30	142 30	3 31	142 45	3 27	141 45
Day Maximum	9 10	47 30	9 40	55 0	9 32	53 0	8 57	44 15
„ Minimum	3 38	144 30	3 30	142 30	3 35	143 45	3 49	147 15
Pressure Increasing, p.m.	7 5	16 15	7 23	20 45	7 9	17 15	7 31	22 45
„ Decreasing, a.m.	1 2	105 30	1 8	107 0	0 58	104 30	1 7	106 15
„ Increasing „	5 29	172 15	6 20	5 0	6 2	0 30	5 30	172 30
„ Decreasing, p.m.	0 17	94 15	0 28	97 0	0 28	97 0	0 24	96 0

The amount of advance in a second at each of the times indicated above in the night period, or of retardation in the day period, with the difference between the rates for two consecutive seconds for each of the months named, are given in the table on page 9.

In dealing with single months it must be borne in mind that, as they embrace two years only, fluctuations are to be expected which would have been neutralised had the observations extended over a sufficient period, but notwithstanding this, the general agreement of the details given above is very striking. Commencing with the night period, as that least affected by extraneous influences, at the solstices the curve crossed the line of mean pressure ascending at 7h. 23m. p.m. in June, and at 7h. 31m. in December; the curve reached its highest point at 10h. 30m. in the former and at 10h. 11m. in the latter, and ultimately crossed the mean, descending at 1h. 8m. and 1h. 7m. a.m. in these months respectively, the time occupied in passing over this portion of the curve being 5h. 45m. in June and 5h. 36m. in December. Entering on the descending portion of the curve at the same time the progress was very similar in both months as far as the minimum, which was reached at 8h. 30m. a.m. in June and 8h. 27m. in December, but here they began to diverge, the curve crossing the line of mean pressure in its ascent at 5h. 30m. in December, while in June it did not reach that point until 6h. 20m., the time occupied being 4h. 23m. in December and 5h. 12m. in June. Coming now to the Equinoxes, the ascending curve crossed the line of mean pressure at 7h. 5m. p.m. in March, and 7h. 9m. in September, it reached its highest point at 10h. 13m. in the former and at 10h. 15m. at the latter, and crossed

Subject.	March.			June.		
	Advance or Retardation, per second.	Difference between successive seconds.	Barometer, + or − Mean.	Advance or Retardation, per second.	Difference between successive seconds.	Barometer, + or − Mean.
	Feet.	Feet.	In.	Feet.	Feet.	In.
Night Maximum	1239·008	·045	+·036	1395·107	·042	+·024
„ Minimum	955·092	·073	—·014	919·263	·087	—·016
Day Maximum	1022·972	·068	+·032	1236·963	·063	+·031
„ Minimum	805·725	·083	—·043	919·263	·087	—·035
Pressure Increasing, p.m.	388·258	·097	..	534·948	·102	..
„ Decreasing, a.m.	1337·036	·026	..	1444·071	·032	..
„ Increasing „	187·105	·100	..	131·607	·109	..
„ Decreasing, p m.	1385·684	·008	..	1495·793	·013	..

Subject.	September.			December.		
	Advance or Retardation, per second.	Difference between successive seconds.	Barometer, + or − Mean.	Advance or Retardation, per second.	Difference between successive seconds.	Barometer, + or − Mean.
	Feet.	Feet.	In.	Feet.	Feet.	In.
Night Maximum	1244·420	·045	+·025	1342·464	·051	+·025
„ Minimum	839·845	·081	—·019	934·815	·086	—·015
Day Maximum.....	1108·105	·061	+·034	1053·701	·079	+·030
„ Minimum	820·442	081	—·035	816 900	·092	—·037
Pressure, Increasing, p m.	411·451	·096	..	583·904	·102	..
„ Decreasing, a.m.	1343·304	·026	..	1445·983	·032	..
„ Increasing „	12·108	·101	..	197·102	·109	..
„ Decreasing, p.m.	1377·157	·012	..	1501·781	·011	..

the mean descending at 1h. 2m. a.m. in March and at 0h. 58m. in September, the time occupied being 5h. 57m. in March and 5h. 49m. in September. The portion of the curve below the line of mean pressure in September passes the point of minimum at 3h. 31m. a.m., and ascends to the mean at 6h. 2m., a space of 5h. 4m., and resembling closely that for June; the corresponding part of the curve for March occupies 4h. 27m., resembling that of December, but the time of minimum seems to have been accelerated by about 20 minutes by one of those accidental fluctuations alluded to above, the real acceleration in the rise like that in December taking place as the curve approached the mean in ascending.

The fluctuations in the early part of the day are no doubt influenced by the changes of temperature then taking place, but there is another factor more powerful in this respect, the operation of which is not only met with at Ascension, but is distinct at St. Helena, and even at Hobart, in Tasmania. The time of the diurnal curve crossing the line of mean pressure ascending, in the morning, at all these places, is earlier than the yearly mean for about six months, and later for the remainder, thus, employing apparent time, the mean occurs at the following hours in the different months at these stations respectively.

Stations.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	Year.
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
Ascension	6 8	5 48	5 30	5 7	5 22	5 29	5 40	6 7	6 20	6 34	6 43	6 21	5 52
St. Helena	6 47	6 26	6 1	5 47	6 6	6 19	6 30	6 56	7 1	6 56	6 53	6 47	6 26
Hobart	5 20	4 45	4 52	4 44	4 26	4 51	5 35	6 39	6 30	6 59	6 20	5 27	5 25

From these figures it is obvious that at Ascension and St. Helena in November the curve commences to reach the line of mean pressure earlier than the mean period for the year, and this goes on until April, both having attained their earliest point in January. At Hobart the first period was from October to March, with the earliest in February. The curve was latest in reaching the line of mean pressure in Ascension in August, and at St. Helena and Hobart in July. These fluctuations did not correspond with the alterations in the time of sunrise, and frequently differed largely from it; thus, at Ascension in January the curve reached the line of mean pressure at 5h. 7m. a.m., while the sun appeared above the horizon at 5h. 45m. only, or 38 minutes afterwards, and in August, while the sun was above the horizon at 6h. 6m. a.m., the curve reached the line of mean pressure at 6h. 43m., or 37 minutes later. The real explanation seems to be that at the beginning of July the Earth is at the most distant point of its orbit from the sun, and in the beginning of January at the nearest, and the Earth's orbital velocity at these points respectively is as 1 to 1·033, and the curve crosses the line of mean pressure latest where this progressive velocity is least, and crosses it earliest where it is greatest; it has been shown already that when the centrifugal action has taken place in front of the advancing body, the latter closed up behind it, reducing the amount of the resulting depression and lessening its duration, and the case under consideration affords another example of the same nature. As the Earth proceeds in its orbit from July to January it reaches its mean distance from the sun at the commencement of October, while moving in the opposite direction it reaches its mean distance in the beginning of April, and these form the nodal points in the fluctuation about the annual mean.

Under the influence of this varying velocity of the Earth in its orbit, the time of occurrence of the day maximum presents a period in fluctuation similar to that of the morning mean. At Ascension the day maximum, on the average of the two years, occurred at 9h. 21m.; taking the respective months singly the time of occurrence was earlier than this from October to April inclusive, with the earliest at 8h. 38m. in January, and was later from May to September inclusive, with the latest 9h. 41m. in July. The descending curve where it crosses the line of mean pressure at midday presents an acceleration in January and the following two months, equally distinct, but not quite half so great as in the case of the maximum or morning mean. The details in the following table for January and July, when these

effects are at their greatest and least amounts, will render the question clearer, and admit of comparison with the results for the whole year already given:—

Subject.	January.		July.	
	Time (Apparent) of Occurrence.	Barometer, + or − Mean.	Time (Apparent) of Occurrence.	Barometer, + or − Mean.
	h. m.	In.	h. m.	In.
Night Maximum, p.m.	10 29	+·027	10 6	+·022
,, Minimum, a.m.	3 13	−·013	3 21	−·020
Day Maximum ,, ...	8 38	+·028	9 41	+·034
,, Minimum, p.m.	3 47	−·043	3 40	−·031
Pressure Increasing, p.m.	7 25	..	7 23	..
,, Decreasing, a.m.	1 17	..	0 59	..
,, Increasing ,, ...	5 7	..	6 34	..
,, Decreasing, p.m.	0 5	..	0 50	..

From these dates the following results are obtained, showing the period occupied in passing from each nodal point in the diurnal curve to the following one in each month, with the attendant oscillation of the Barometer:—

	January.			July.		
	Time Occupied.		Barometer.	Time Occupied.		Barometer.
	h.	m.	In.	h.	m.	In.
Above Mean Pressure, Night Period	5	52	+·027	5	36	+·022
Day Period	6	58	+·028	6	16	+·034
Below Mean Pressure, Night Period	3	50	−·013	5	35	−·020
Day Period	7	20	−·043	6	33	−·031

These it will be seen bear out the remarks made above as to the effect of the varying velocity of the Earth's orbital motion on the times of occurrence of the various phases of the diurnal curve, and on their amount. These, with the facts previously mentioned, place it beyond doubt that the diurnal oscillation of the barometer is mainly due to the combination of the Earth's rotation with its orbital motion.

The extremely favourable geographical position of Ascension, by minimising the disturbing elements of large tracts of land, has permitted me to derive these results from the comparatively limited series of observations of Lieut. Rokeby there, and though more extended experience hereafter may suggest minor modifications, the leading principle will remain.

DISCUSSION.

Mr. STRACHAN was unable to follow the paper further than to perceive that the theory was one which had been broached before. It will be found in *An Essay on the Nature and Cause of the Diurnal Oscillation of the Barometer*, by Graham Hutchison, published in 1844. Hutchison's books are readable, but they are scarcely ever referred to, and probably little read, and no wonder, as there is

such an immense number of works now published on meteorology that no one can hope to read anything like all of them. The author of the paper just read had, however, made a great stride with the theory, inasmuch as he had gone into elaborate astronomical calculations, and applied them to observed meteorological data. Before the solution of the problem could be accepted it would be necessary to examine the data and the method very carefully. But, whatever opinion might thus be arrived at, there could be no question that the study of this evidently very tough problem would lead to good results, and the author's memoir would be found fruitful of suggestions.

Dr. LAWSON said he had not heard of the remarks of Hutchison referred to by Mr. Strachan. He was not aware of any detailed observations over the sea; but under any circumstances they could not have the same weight as those made at a fixed point by a competent observer, and continued for a period of two years.

The SECRETARY read some extracts bearing on the subject from a translation of Goethe's "Attempt to form a Theory of the Weather" which had been forwarded by Mr. Cann Lippincott.

RAINFALL ON AND AROUND TABLE MOUNTAIN, CAPETOWN, CAPE COLONY.

By JOHN G. GAMBLE, M.A., M.Inst.C.E., F.R.Met.Soc.

[Read November 16th, 1887.]

THE differences that exist between the quantity of rain that is registered at the several gauges on and around Table Mountain are so great, and in some respects so peculiar, that they deserve special inquiry.

I have therefore prepared a plan of the district showing the positions of the various gauges, with their height above sea-level in feet and the average annual fall in larger figures above. I have also drawn two sets of annual curves of mean monthly rainfall at these stations, and I venture to think that this map and these curves may be of interest to the Society.

Table I. gives the monthly averages for each station, taken for as many years as were available in each case. These figures are shown graphically on one of the sets of curves, and the annual totals are those marked on the plan.

Table II. gives the monthly averages for the same stations for the four years 1883, 1884, 1885 and 1886, thus making the results more strictly comparable. These are shown on the second set of curves.

Perhaps the most striking feature is

TABLE I.—Rainfall near Table Mountain.

Position of Gauge.	No. of Years for which averages are taken.	Height above Sea.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
		Ft.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Waai Kopje	5	3100	0·92	2·02	3·11	4·65	7·82	9·38	6·31	7·57	5·08	5·11	1·98	2·75	56·70
Newlands	4 to 6	83	0·14	1·31	2·09	4·38	9·04	9·53	6·74	8·53	4·63	5·44	1·77	2·03	55·63
Bishop's Court	15	250	0·99	1·34	1·64	3·42	8·45	9·80	6·81	7·15	5·59	4·33	2·20	2·19	53·91
Platteklip	5	550	0·77	1·48	2·26	3·48	5·53	7·81	7·05	5·13	4·49	3·64	1·66	1·75	45·01
Wynberg	18	250	0·57	1·02	0·97	2·26	6·71	8·05	6·85	6·01	4·32	3·24	1·85	0·90	42·75
Rondebosch	7	100	0·87	0·75	1·71	2·82	5·59	6·53	6·19	5·95	3·52	2·75	1·35	1·51	39·54
Disa Head	5	2500	0·51	1·04	1·92	4·74	5·01	5·98	5·32	5·06	3·28	2·62	2·02	1·41	38·91
Kloof Street	4 to 5	450	0·52	1·00	1·86	2·30	3·97	5·47	4·95	3·92	3·66	3·04	1·09	1·18	32·96
Town House	22	88	0·47	0·69	0·89	1·74	4·39	4·86	4·27	3·76	1·90	1·82	0·99	0·92	26·70
Royal Observatory	42	37	0·67	0·61	0·96	1·83	3·93	4·42	3·46	3·34	2·11	1·58	1·09	0·81	24·81
Sea Point	7	15	0.33	1·00	0·57	1·56	2·53	4·10	3·28	2·07	1·48	2·47	0·81	0·45	20·65
Green Point	3 to 5	100	0·19	0·90	0·97	1·37	2·04	3·73	3·37	2·18	2·10	1·70	0·56	0·95	20·06
Signal Hill	3 to 5	1143	0·08	0·73	0·88	0·95	2·02	2·32	2·15	1·80	1·40	1·46	0·32	1·06	15·17

TABLE II.—Monthly Average Rainfall for the Four Years, 1883, 1884, 1885 and 1886.

Position of Gauge.	Height above Sea.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	Ft.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Waai Kopje	3100	1·10	2·19	2·95	3·74	8·42	9·48	7·25	6·90	6·84	5·17	2·80	2·08	58·92
Newlands	83	0·14	1·49	1·80	3·03	7·26	11·15	7·33	8·07	5·55	5·37	2·06	1·69	54·94
Bishop's Court	250	0·64	1·06	2·22	3·22	8·25	12·00	6·76	6·51	7·54	6·16	2·13	1·53	58·02
Platteklip	550	0·76	1·49	2·26	3·05	6·18	8·35	6·05	5·44	4·91	3·52	1·85	1·35	45·21
Wynberg	250	0·40	1·08	1·77	2·31	7·03	9·51	5·15	4·82	6·14	4·69	1·49	0·88	45·27
Rondebosch	100	0·48	0·99	1·67	2·46	5·43	8·78	6·11	6·76	4·10	3·38	1·47	1·34	42·97
Disa Head	2500	0·62	1·13	1·95	2·13	5·20	5·81	4·24	4·23	3·68	3·09	1·75	1·15	34·98
Kloof Street	450	0·52	1·00	1·86	2·31	4·52	5·46	4·31	4·15	3·95	2·94	1·30	0·78	33·10
Town House	88	0·38	0·81	1·30	1·52	3·17	4·28	3·13	2·51	2·26	1·85	0·82	0·35	22·38
Royal Observatory	37	0·50	0·83	1·41	1·61	3·12	5·43	3·32	2·92	2 85	2·71	1·21	0·67	26·58
Sea Point	15	0·79	0·97	1·14	1·27	1·86	4·31	2·29	2·02	2·33	1·82	0·72	0·50	19·42[1]
Green Point	100	0·19	0·90	0·96	1·17	2·37	3·99	3·03	2·25	2·27	1·66	0·66	0·54	19·99[2]
Signal Hill	1143	0·08	0·73	0·88	0·89	2·12	2·42	2·05	1·79	1·44	1·49	0·39	0·54	14·82

[1] Mean for 3½ years. [2] Mean for 3½ years.

the small fall on the Signal Hill. The Signal Hill, otherwise called "the Lion's Rump," lies to the west of Capetown, between it and the Atlantic. The average annual fall there is only 15 ins., while the fall at the western foot is 21 ins., and in Capetown 27 ins. The Signal Hill is 1,143 feet above the sea. I do not remember any similar case elsewhere of such a peculiarity. It will be seen that the fall at Platteklip, on the Northern slope of Table Mountain, overlooking Capetown and 550 feet above the sea, is considerable, namely 45 ins.

The greatest fall is at Waai Kopje, about half a mile to the southward of the highest point of the mountain, at an elevation of 3,100 feet, or 450 feet below the top. Another station on Table Mountain further south, that is, to the leeward in the rainy season, and 2,500 feet above sea-level, has only 39 ins.

The Eastern suburbs, Rondebosch, Newlands, and Wynberg, all have a comparatively abundant rainfall, 40 to 50 ins. and upwards, the greater part of which falls in winter time.

The principal wind in winter is the North-west; in summer is the so-called South-east, often nearly due South. Easterly and North-easterly winds are of rare occurrence, and South-westerly winds, though more frequent, do not last long.

There are a few more gauges now being kept in this district, but their registers do not embrace four complete years, and have therefore been excluded from these Tables.

DISCUSSION.

Mr. TRIPP said that the rainfall at all these stations, while it varied so considerably in the amounts, did not vary much as to the comparative quantities falling at each season, June was the wettest month at all the stations. There was, however, a peculiarity which distinguished the stations to the North-east of Table Mountain, and one station on the mountain, from those to the West of it, inasmuch as, while at some of the former August was a wetter month than July, this was not seen at the latter, where the fall decreased regularly from June. The great variation in the mean fall without difference of season was also seen in the rainfall of particular years, for instance during the wet year 1883 there was a great variation in the falls at stations on and around the Cape Peninsula. The variation might, perhaps, in both cases be largely due to the position of the stations respectively with reference to the mountains with which the Cape Peninsula is studded.

Dr. BLACK said that the rainfall of Table Mountain was before known to be greater on one side than on the other. He thought that the variation in the rainfall amounts was probably due to the gauges being on the hill slopes, and the wind blowing the rain over or into the gauges. Signal Hill was a very windy spot, besides being bare, and would therefore get a diminished rainfall. Vegetation attracts moisture, and therefore the eastern slopes would naturally have more rainfall than the western, which were bare.

THE MEAN TEMPERATURE OF THE AIR AT GREENWICH,

From September 1811 to June 1856 inclusive.

By HENRY STORKS EATON, M.A., F.R.Met.Soc.

[Read December 21st, 1887.]

In 1882 this Society acquired by purchase the MS. Meteorological Journals of the late Mr. John Henry Belville, who from his youth was on the staff of the Royal Observatory, Greenwich. They are contained in ten volumes, and extend from March 1st, 1811, to July 7th, 1856, being within a few days of Mr. Belville's death.

The Journals include observations of the barometer, thermometers, de Luc's hygrometer, cloud, rain, wind, and weather, and, in the latter years, of the dry-bulb and wet-bulb thermometers, and with the exception of the first year or two were kept with great care. There are also numerous notes relating to gales of wind, thunderstorms, severe frosts, periods of high temperature, and what are now termed phenological phenomena. The present communication is confined to a discussion of the observations of the temperature. Very little is said about the thermometers themselves, or their mode of exposure. It may, however, be inferred that the thermometers were the best procurable, and that they were attached to the external walls of the dwelling-houses successively occupied by Mr. Belville, with as far as possible a northern exposure. The notes bearing upon the instruments have been transcribed, and are given at length in the Appendix.

From the commencement till October 1822 the observations were made at the Royal Observatory, the staff at this time being lodged on the premises; and it is believed that the thermometers were suspended in the forecourt of the Observatory outside what is now the transit room. In November 1822 the instruments were removed to Park Row, east of the Royal Hospital, and about 180 yards from the River Thames. In August 1825 they were taken to Park Terrace, at the foot of Maze Hill; on the 22nd of February 1833 to Blackheath Road, about 420 yards east-south-east from Deptford Bridge, and near the foot of Blackheath Hill; on the 11th of August 1840 to Prior Street, near the bottom of Royal Hill; and finally on the 1st of February 1844 to Hyde Vale, on rising ground leading to Blackheath. From measurements taken on the 6-inch Ordnance Map of the district, it appears that the greatest distance between any two of these stations is 1 mile and 40 yards, Park Terrace being that distance north-east by east from Blackheath Road. Prior Street is almost exactly on the straight line joining them, and 617 yards from Blackheath Road. Park Terrace is 600 yards north-north-east from the forecourt of the Royal Observatory, and 220 yards east by south from Park Row; and Hyde Vale is 283 yards south-east by east from Prior Street, and 572 yards nearly west-south-west from the forecourt of the Royal Observatory.

Before commencing their reduction, the individual observations were compared with those entered for the same day in the Meteorological Journals of

the Royal Observatory, the author having obtained through the courtesy of Mr. Christie, the Astronomer Royal, a certified copy of all the temperature observations from the commencement of the Journals in 1807 to the 31st of December 1840, by which time the then recently established Meteorological Department was in working order, and the old series of temperature observations was discontinued. These two sets of observations were further compared with those made on corresponding days at the Royal Society's apartments, Somerset House; at Carey's, in the Strand; and with the observations recorded in Luke Howard's *Climate of London*. The character and quality of these latter observations is not now in question; but the author has thought it expedient to discuss the Royal Observatory Journals in conjunction with Mr. Belville's, as they are closely connected. This is evident from the earlier observations. From 1815 up to the month of October 1826 the entries in the two sets of Journals are practically identical, and seem to have been taken from some common source of information, in fact the monthly means are the same; but it is expressly stated in Mr. Belville's Journal that "after this month (October 1822) the observations were discontinued at the Royal Observatory, and were carried on at Park Row, Greenwich," and since there is no break in the continuity of the Royal Observatory Journals, it follows that for a period of four years the entries in the latter were copies of Mr. Belville's observations at Park Row and Park Terrace. In November 1826 independent observations were resumed at the Royal Observatory, and have since been carried on there continuously.

There are very few interruptions in the continuity of the Belville Journals. Often for months together not a single one of the four daily observations is missing; but when any interruption does occur allowance has been made on the assumption that the deficient observation, or observations, for the particular hour of the month in question bears the same ratio to the recorded observations at that hour as is found to obtain at the same or nearest hour at neighbouring stations where the record is unbroken. In two months only are the data for computing the mean monthly temperature from the Journals themselves insufficient, namely, in July 1823, when only 27 observations were entered, these being at noon; and in September 1844, when only the daily maximum and minimum temperatures were recorded.

The hours of observation first adopted by Mr. Belville were somewhat irregular, having been chosen as affording a clue to the approximate daily range of temperature. Beginning with December 1811 the thermometrical observations were taken thrice daily, namely, at 7 a.m., 2 or 3 p.m., and 10 p.m. in summer; at 8 a.m., 1 or 1.30 p.m., and 9 or 10 p.m. in winter; and at 7.30 a.m., 2 p.m., and 10 p.m. in spring and autumn. From January 1815 to October 1822 the hours were 8 a.m., noon and 10 p.m.; and from November 1822 to the end of the series in July 1856 they were 8 a.m., noon, 4 p.m. and 10 p.m. Observations of the extremes of temperature by Six's thermometer were first taken in April 1814, and the daily maximum and minimum temperatures were noted from January 1827. The Journals and

Tables show from internal evidence that Mr. Belville was an excellent and careful observer, and in this respect far in advance of the meteorologists of that day.

Subsequently to Mr. Belville's leaving the Royal Observatory as a place of residence, on the resumption of observations there in November 1826 the hours were the same as had been selected by Mr. Belville, namely, 8 a.m., noon, 4 p.m. and 10 p.m.; and for the following four years and three months the observations are strictly comparable with those taken at Park Terrace. In April 1831 these hours were altered to 9 a.m., noon, 3 p.m. and 6 p.m.; in October 1835 to 9 a.m., noon, 2 p.m. and 6 p.m.; and finally in April 1836 to 9 a.m., noon and 2 p.m. Throughout this Paper the observations up to the end of the year 1840 are referred to as the "Old Series;" those subsequent to that date as the "New Series."

With respect to the New Series of thermometrical observations inaugurated at the Royal Observatory in December 1840, and carried on to the end of December 1847, the individual observations and the results obtained from them were published in a volume for each year. As in the case of other elements of research, however, their reduction was not completed. The main object sought for was to ascertain the diurnal range of temperature; on Sundays and holidays only a limited number of observations were made, and these were not taken into account in the Tables, while corrections for instrumental error were also neglected. The twelve daily eye observations on the six working days of the week were made at the even hours Göttingen mean time, which is nearly 40 minutes in advance of Greenwich time. The author therefore recomputed the whole of this series, giving due consideration to each of the points referred to above, and using Belville's Journals in estimating interpolations for days of deficient or of no observations, adopting the system of ratios throughout. The results were then plotted on diagram paper, curves projected through them, and the mean temperature of the month for every hour, Greenwich mean time, was read off and tabulated. The author believes that, apart from any question that may be raised upon the exposure of the instruments, which is fully described in the *Greenwich Magnetic and Meteorological Observations*, the results now given in Table VI. in the Appendix represent for the first time the correct monthly temperatures at the Royal Observatory from December 1840 to the end of 1847. The differences, however, from the values hitherto published are slight, and are principally owing to the application of corrections for index errors of the instruments.

As a preliminary to the reduction of the Belville Journals, and those of the Royal Observatory up to the end of the year 1840, which is the main object of the present communication, curves of the mean hourly temperature of every month of the year at the Royal Observatory for a period of 30 years were laid down on diagram paper. These were arrived at by a combination of the values contained in the *Reduction of Twenty Years' Photographic Records* with those deduced by the author for the series 1841-47, given in Table VI., and the years 1880, 1881 and 1882, which have been published. The scale of ordinates was 1 inch to one hour, and of abscissæ 0·5 inch to 1° Fahrenheit.

Curves were also similarly projected for months of very high and very low temperature, and for those wherein the diurnal range of temperature was much in excess or in defect of the average. These curves were only used as a check upon the subsequent reductions, being graphic indications of the general diurnal variation of temperature at the Royal Observatory for every month of the year under different conditions of temperature.

In the next place, after an examination and inter-comparison of the individual entries in the Belville and Royal Observatory Journals, the mean temperature of the month at each place at the fixed hours of observation was ascertained and tabulated. The corrected mean temperatures for the various hours, calculated from Belville's observations, were then plotted on the same diagram paper and curves projected through them. In drawing a curve, its form was to some extent influenced by the averages of the daily maximum and minimum temperatures of the month under investigation, as ascertained by the self-registering thermometers, these points being marked by a dot on the diagram paper at the times of day at which the average lowest and highest temperatures are known to occur; and any seeming irregularity was at once noted and examined. The readings at every hour were now tabulated, and the mean taken as the mean temperature of the month (Table I).

The same process was pursued in the reduction of the Royal Observatory temperature observations (Table II). By this method it soon appeared that for several years before their termination in December 1840 the recorded observations of temperature at the Royal Observatory were untrustworthy, the first morning observations and those taken at 6 p.m. being frequently too high, and the curves consequently distorted. In addition to this, observations were partially given up on Sundays and holidays after January 1832, and entirely so at the end of 1835, while the Journals were otherwise very imperfect; and the method of interpolation pursued in the case of the Belville Journals was often not possible. In all such circumstances the results have been rejected, and hence the deficiencies in Table II. of the average monthly temperatures. But at best the values in this Table are somewhat doubtful, as they mainly depend upon observations crowded towards the middle of the day, especially for the last four and a half years of the "Old Series," when nineteen consecutive hours elapsed without an observation, namely, from 2 p.m. on one day to 9 a.m. on the next, and between the last observation on Saturday and the first observation on Monday the interval was as much as forty-three hours; whereas in the Belville Journals it never exceeded ten hours. The self-registering thermometers at the Royal Observatory were also frequently out of order.

The hourly mean temperatures were now ascertained for the various stations separately (Table VII), and the whole Belville series combined is given in Table III. It is to be regretted that the Old Series of observations at the Royal Observatory is not sufficiently accurate nor complete to afford a satisfactory comparison with the above from 1832 to 1840; but the observations from November 1826 to February 1831, which are much better, have been compared with those at Park Terrace (Table IX). Here it will be noticed

that the daily range of temperature at Park Terrace (10°·4) is 0°·8 greater than at the Royal Observatory (9°·6), the temperature falling 0°·5 lower at night and rising 0°·3 higher by day at the former station at the lower elevation. This is supported by the self-registering instruments, the record of which is unbroken at the two stations for the years 1828 and 1830, when the averages of all the daily maximum and minimum temperatures and the daily range were respectively :—

	Maximum.	Minimum.	Daily Range.
Royal Observatory ...	56°·30	43°·20	13°·10
Park Terrace	56°·45	42°·79	13°·66

The small daily range of temperature of 9°·7 at Park Row, notwithstanding it is only 25 feet above sea level, may be attributed to the proximity of this station to the Thames and the modifying effect of that river, but it is based on too short a period of time to be of much weight.

No trustworthy comparison can be made between the observations at Blackheath Road and the Royal Observatory, owing to the faulty condition of the register at the latter station. The large range (11°·0) at Blackheath Road, greater here than at the other stations, is, however, no doubt to some extent due to its small elevation (30 feet) above sea level; but there is another cause in operation. Blackheath Road is near the Ravensbourne, and though the river itself is of too small a volume sensibly to affect the temperature, the station is evidently within the influence of a current of cold air which sets down the river valley at night in fine dry weather towards the Thames. This, while reducing the temperature, increases the range, and is a feature common to the river basins of the district, as the author has shown elsewhere.[1] A notable instance occurred in the intense frost of the 20th of January 1838, particulars of which are given in the Appendix. On the other hand, the Royal Observatory is on the edge of a steep declivity, and, as will be seen from Table IX., enjoys a comparatively high night temperature.

The subsequent comparisons are with the New Series of observations at the Royal Observatory, when the instruments were much more freely exposed. The stand itself and the way in which the instruments were attached to it is fully described in the Introduction to the *Greenwich Magnetical and Meteorological Observations*; it is now generally known as the "Glaisher Stand," and was brought into operation on the 23rd of March 1841. The following extract from the "Introduction" describes the positions successively occupied by the stand :—"A post was planted in the year 1841 in the north-east re-entering angle of the magnetic observatory, about 6 feet from the walls of the building, and upon this a revolving frame was placed for carrying the thermometers. The post remained in this position till 1846, July 20th, and on July 22nd it was planted in a position 23 feet south of the south-east angle of the south arm of the magnetic observatory."

It is stated that the aspect of the self-registering instruments at Prior

[1] *Transactions of the Croydon Microscopical and Natural History Club*, 1884-85, p. 76.

Street was due north; the street extends from north to south, and the station is sheltered by houses on the eastern side; hence the comparatively low readings of the thermometer in the morning. In the afternoon, on the sun coming round to the west, an opposite condition prevailed, and the temperature was raised by heat reflected from the surrounding buildings; this was noticed on one occasion as early as the 7th of March, and it was a marked feature in the summer months.

Of Hyde Vale Mr. Belville has written, "The locality does not appear favourable for very high degrees of heat, the instruments being in a hollow or glen, encompassed with hills and trees and lofty houses to the south." Here, as compared with the Royal Observatory, the temperature is depressed for several hours before and after noon. But it seems probable that the temperature observed with the instruments exposed on the revolving stand at the Royal Observatory is too high; since on bright days, when the sun is north of the Equator, the maximum temperature is several degrees higher on this stand than in a Stevenson screen, which excludes reflected heat. The higher mean temperatures by the New Series and by the subsequent photographic reductions must not, therefore, be taken as a proof of a secular increase of temperature of late years. The author anticipates that on further investigation some reduction will have to be made in the mean temperatures of the summer months at the Royal Observatory as at present calculated, to render them comparable with the observations at other stations, inasmuch as hitherto all the photographic reductions have been based on the reading of the dry-bulb thermometer on the revolving stand.

The monthly and annual mean temperatures at Greenwich from Belville's observations reduced to sea-level, Table V., have been derived from Table I. by adding to the values therein contained the amounts due to the elevation of the several stations, being at the rate of 1°·0 for 270 feet.[1] These are 0°·1 for Park Row, Blackheath Road, Park Terrace, and Prior Street; 0°·2 for Hyde Vale; and 0°·6 for the Royal Observatory. Dividing the 44 complete years of observation into four periods of 11 years each, and again into two of 22 years, the results are respectively :—

Period.	Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1812 to 1822	36·2	39·3	42·1	47·0	53·3	59·0	61·6	61·4	56·9	49·7	43·3	37·9	48·95
1823 to 1833	34·9	38·9	41·5	47·2	54·0	59·2	62·8	61·3	56·9	51·0	43·2	41·2	49·35
1834 to 1844	37·1	37·9	41·8	45·7	53·0	59·8	61·7	61·9	56·6	48·5	43·1	39·0	48·84
1845 to 1855	38·9	38·5	40·6	46·1	53·0	59·6	62·8	61·3	56·3	50·3	43·7	39·9	49·25
1812 to 1833	35·5	39·1	41·8	47·1	53·6	59·1	62·2	61·3	56·9	50·4	43·3	39·6	49·15
1834 to 1855	38·0	38·2	41·2	45·9	53·0	59·7	62·2	61·6	56·7	49·4	43·4	39·5	49·05
1812 to 1855	36·8	38·6	41·5	46·5	53·3	59·4	62·2	61·5	56·7	49·9	43·3	39·5	49·10

[1] *Journal of the Scottish Meteorological Society.* Third Series, Vol. VIII. p. 7.—Meteorology of Ben Nevis. First Report. By Alexander Buchan, 1884.

The general results to be gathered from this investigation seem to be :—

1. That there was no appreciable change in the mean annual temperature of the air at Greenwich in the period 1812 to 1855 inclusive.

2. That on the eminence on which the Royal Observatory is situated the average temperature at night, or rather the early morning, is in all cases higher than over the lower grounds.

3. That with a north-wall, or possibly a north-window exposure, higher maximum temperatures are found at the lower stations.

4. That the movements of the thermometer are retarded with a north-wall exposure as compared with an instrument on an open stand, especially where the situation is a confined one, the indications of the thermometer not following changes of temperature so promptly owing to the modifying influence of the adjacent building.

A complete account of all the reductions used in this investigation would occupy too much time ; but the author has arranged for reference and placed in the Library the following Tables :—

1. A verified copy of all the air temperatures as observed at the Royal Observatory, Greenwich, during the years 1807 to 1840, with sums and means for every hour of observation for each month.

2. Sums of the monthly temperatures at every hour of observation, also of the daily maximum and minimum temperatures, from Belville's observations, September 1811 to June 1856.

3. Means of the above, showing also the number of deficient observations for which interpolations were made.

4. Mean monthly temperatures at every hour of observation, from observations taken at the Royal Observatory, Greenwich, between January 1807 and December 1840.

5. Hourly temperatures for every month, from September 1811 to June 1856, with the exception of July 1823 and September 1844, computed from diagrammatic curves, from Belville's observations. With totals and means for the separate stations and for all combined.

6. Ditto, from November 1826 to December 1840, from observations at the Royal Observatory, Greenwich, so far as consistent with diagrammatic curves.

7. (1.) Mean temperature of the air at every hour of the day for the month and for the year at every station, from Belville's observations.

(2.) Excess or defect from the mean temperature of the month and of the year, deduced from the above.

8. Comparison between mean hourly, monthly and annual temperature of the air at Park Terrace and the Royal Observatory (Old Series), from November 1826 to February 1831.

9. Ditto, between Prior Street and the Royal Observatory (New Series), from December 1840 to January 1844.

10. Ditto, between Hyde Vale and the Royal Observatory (New Series), from February 1844 to December 1847.

11. Miscellaneous.

APPENDIX.

1. Extracts from the Belville Journals.

From the beginning to October 1822 at the Royal Observatory. From October 1822 to July 1825 at Park Row. From July 1825 to February 1833 at Park Terrace. The two last localities might be considered nearly as one, the distance being so small. Park Place (at the eastern end of which Park Terrace is situated) is about 120 feet lower than the Observatory.

1811, October. From observations at 7 a.m. and 2 p.m., which might be considered nearly as the minimum and maximum of temperature, the deduced mean is 56°·5, the warmest month of October on record.

1812, August. The rough paper on which the thermometers were registered for the greater part of the month was lost, therefore the average temperature cannot be ascertained with any degree of accuracy.

1818, July 24th. Thermometer 8 a.m. 80°, noon 88°·5, 10 p.m. 72°. At 3 p.m. 93°·5 (maximum), minimum 66°. On July 14th, 1808, the thermometer was 95°.

1820, January 15. Thermometer no higher than 3° in the morning. A thermometer was exposed detached from the house at 11 minutes past 9 a.m. and it fell to 3°. I should be led to imagine that about sunrise it was at zero in the same place.

1822, October. After this month the observations were discontinued at the Royal Observatory, and were carried on at Park Row, Greenwich, till July 1825, when the instruments were removed to Park Terrace.

1831, May 2. This evening happening to be one of general illumination, bonfires, &c., it is probable the thermometers out of window were not taken very exactly, or even indicated the true state of the air. September 8. There was a general illumination this evening. The temperature somewhat uncertain.

1832, June 7. The lightning fell opposite the house in the Park.

1833, February 22. The meteorological instruments were removed from Park Terrace, Maze Hill, to Blackheath Road. The height above the Thames about 30 feet only.

November 3. Errors of thermometer. New minimum +0°·4. W. Rad. —1°·0. D. Rad. +1°·0. Mean of two radiators near the truth. Subtract 0°·4 from the minimum.

1837, February 14. Maximum 50°·5. Radiation from bright cumuli to the north.

1838, January 19. Blackheath Road. Thermometer at 8 a.m. 19°, noon 19°, 4 p.m. 17°, 10 p.m. 15° ; 20th, 8 a.m. —4° wind South, 9 a.m. —2°, 10 a.m. +1°·5. 11 a.m. +4°·0, noon +7°, 1 p.m. 12°·5—on the snow 8° sky cloudless, 2 p.m. 16°·5 brilliant sunshine wind East and light fleecy clouds coming up from the west, 3 p.m. 17°·5 wind East, 4 p.m. 15°·5, 7 p.m. 14°, 10 p.m. 15°.

January 19. At 19 George Street, Greenwich, in a crowded yard surrounded by high walls, thermometer at 6.30 p.m. 14°·5, 7 p.m. 13°·8, 7.30 p.m. 15°, 9.30 p.m. 16°·5, 11 p.m. 14°, midnight 12°·5 ; 20th, at 1 a.m. 7°, 1.30 a.m. 6°·1, 1.45 a.m. 5°·5, 2.20 a.m. 5°, 3 a.m. 3°·8, 7.30 a.m. 2°·5, 8 a.m. 2°·2, 8.15 a.m. 2°·5. The minimum about 2°. At Hudson's, Optician, near Deptford Bridge, minimum temperature —5° ; at Mr. Wrottesley's Observatory, Blackheath, —2°·5 ; at Mr. Brown's, Lewisham, —6° ; at Beckenham, —8° or —10°.

June 12. At noon thermometer 68° from solar reflection ; the maximum thermometer 65°·9. July 13. The standard mercurial thermometer 83° about 3 p.m. Maximum 81°·5. (From this date till the 23rd of June 1850 there are frequent entries of 'maximum temperature doubtful' or 'too high' from reflection and radiation from 'white' or 'bright' clouds, cumuli and cirro-cumuli—estimated sometimes as too high by as much as 3°.)

1839, February 19. Great variation of temperature as indicated by thermometer at different heights. The standard register 26°, which agrees with the mercurial thermometer.

1840, August 11. The meteorological instruments were removed from Blackheath Road to Prior Street, Greenwich, a distance of nearly half a mile eastward of the former Station, and very near the foot of Royal Hill leading on to the Point at Blackheath. The aspect of the self-registering thermometers is due north, and the elevation about 10 feet more than at Blackheath Road.

1841, September. One line is supposed to contain all the readings of one day

(twenty-four hours). The minimum of the thermometer and the maximum likewise belong to the same day on which they are read off. Thus on the 1st September 1841 the minimum 49° occurred probably a little before sunrise of the 1st and the maximum 66°·7 in the course of the same day, therefore they are placed in the line against September 1. The minimum readings are taken generally every morning and the maximum readings every afternoon or evening, and whenever the maximum may not have taken place during the day the thermometer is then read off about midnight, showing the maximum for the twenty-four hours. This is not of very unfrequent occurrence during the winter months. With respect to the minimum reading, if the lowest temperature after sunrise has not yet arrived, the reading is not taken till the index is left by the rising of the alcohol. This very rarely happens, and only during one or two of the winter months at the setting in of frosts, or in violent storms, &c.

1842, July. The observations were made from July 10 to August 10 by Mr. Rogerson, George Street—a distance of about 1 furlong from Prior Street.

August 18. At 3.30 p.m., about the time of the greatest heat, a thermometer in the street window but in the shade and facing the east marked 93°, in the garden 93° and 94°. The highest degree of heat indicated by the register in the coolest part of the garden against a north wall and near tall shrubs was 90°·2 between 3 and 4 p.m.

1843, March 7. Maximum of temperature (between 2 and 3 p.m.) considered too high from the heat of the sun reflected from the adjacent houses.

1844, February 1. The meteorological apparatus was removed from Prior Street to Hyde Vale. The latter place bears S.E. of Prior Street, and is situated just at the N.W. extremity of Blackheath. Hyde Vale is on a rising ground leading to the Heath, and is about 30 feet higher than Prior Street. The garden in which the instruments are placed has a northern aspect. The eastern horizon is bounded by the steep hill leading to the top of Blackheath. The distance from Prior Street might be about 1 furlong, and is nearer by ½ furlong at least to the Royal Observatory, and about 70 feet only lower.

1845, March 5. An exposed thermometer in a privet bush never rose higher than 29°. The maximum rose to 31°. March 13. Old Standard mercurial thermometer at parlour window 10 a.m. 23°; 2 p.m., 23°·7 (maximum); 10 p.m. 16°; midnight, 15°. (From ordinary register thermometer, 8 a.m. 22; noon 23°; 4 p.m. 22°; 10 p.m. 16°·5.) A small mercurial thermometer was suspended on the north side of a large privet bush in the forecourt of the Royal Observatory. It was observed every quarter of an hour between 9 a.m. and 2 p.m., and was never seen higher than 22°. The thermometer was suspended so as to have no reflection from the sun shining on any wall, and exposed to the free current of wind, which was blowing strong. The temperature might stand 1° higher at Hyde Vale, from the locality and the reflection of the sun's rays from the opposite banks.

1846, July 4. (From ordinary register, thermometer 8 a.m. 65°; noon, 80°; 4 p.m. 84°; 10 p.m.. 67°. Minimum, 53°·4; maximum, 84°). On a privet bush at the Royal Observatory the temperature rose to 86° at 2 o'clock in the shade. The locality of Hyde Vale does not appear favourable for very high degrees of heat, the instruments being in a hollow or glen encompassed with hills and trees, and lofty houses to the south.

1848. Observations from the 10th of August to the 8th of September by W. Ellis.

1850, May 23. Maximum 70°·5, only a minute's duration, caused by the reflection from bright cumuli to the northward. August. From the 12th to the 31st observations by W. Rogerson.

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2. Extract from the Royal Observatory Journal.

1838, January 20.[1] The register thermometer was deranged. The minimum at the Observatory was about 3°, which took place at sunrise; 9 a.m., tin tube thermometer 6°, in glass tube, 5°·6; 10 a.m., thermometer 7°·5, at 11 a.m. 7°·7; 11.30 a.m., 11°; (from ordinary register, 9 a.m., 5°·8; noon, 14°; 2 p.m, 16°·5).

[1] The Mean Temperature of the Air on this day at Blackheath Road, obtained by the graphic method was 7° and at the Royal Observatory 11°·1, but the latter is doubtful, as no observations were taken there after 2 p.m.

TABLE I.—Mean Temperature of the Air at Greenwich deduced from Belville's Observations, September 1811 to June 1856.

Royal Observatory, 155 feet above Ordnance Datum.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1811	..	..	..	..	..	..	..	..	57·3	54·8	44·4	36·8	..
1812	35·4	41·2	38·5	42·3	53·7	56·3	58·9	58·4	54·9	49·5	39·7	33·6	46·9
1813	33·7	42·0	43·2	46·7	55·3	57·7	59·6	59·8	55·5	47·4	39·7	36·0	48·1
1814	26·3	31·5	36·5	49·6	49·6	54·8	63·6	60·5	55·5	47·1	40·8	41·1	46·4
1815	32·3	43·8	45·4	46·3	56·3	60·1	60·6	61·6	57·3	50·2	38·1	36·4	49·0
1816	36·3	34·5	39·2	43·7	49·6	55·8	57·6	57·1	53·9	50·1	38·5	37·3	46·1
1817	39·5	43·1	40·7	42·3	48·0	60·1	58·3	57·1	56·8	43·5	48·2	36·5	47·8
1818	40·1	35·7	40·6	45·6	52·3	64·4	67·7	63·0	57·7	52·9	48·3	36·8	50·4
1819	39·8	39·7	43·3	47·8	55·1	57·2	62·3	65·0	57·6	48·9	40·3	35·6	49·4
1820	31·3	35·8	39·4	48·3	53·1	57·1	60·6	60·6	54·0	47·2	41·2	39·8	47·4
1821	37·8	34·8	42·7	50·4	50·1	54·5	58·7	63·2	60·2	50·2	48·2	44·2	49·6
1822	39·1	43·2	46·6	46·9	56·1	64·2	62·6	62·0	56·2	52·9	..	..	..

Park Row, 25 feet above Ordnance Datum.

	°	°	°	°	°	°	°	°	°	°	°	°	°
1822	..	..	..	..	..	..	..	..	..	..	47·4	34·0	..
1823	31·1	38·6	40·4	44·9	55·7	56·6	(58·5)	61·0	55·8	48·2	44·0	40·9	(48·0)
1824	38·3	39·9	41·1	45·3	51·1	56·9	63·9	61·7	59·0	50·5	46·8	42·5	49·7
1825	39·1	38·6	39·0	49·1	53·8	58·7	65·1	..	..	..	..	..	..

Park Terrace, 40 feet above Ordnance Datum.

	°	°	°	°	°	°	°	°	°	°	°	°	°
1825	..	..	..	..	..	..	..	63·0	60·8	51·5	41·8	40·9	..
1826	31·0	42·6	41·8	48·8	51·0	63·6	66·1	66·4	58·1	52·8	40·4	42·6	50·4
1827	34·2	31·9	43·2	48·2	54·2	58·3	63·8	59·3	57·7	52·3	42·8	44·7	49·2
1828	40·4	40·5	43·1	47·6	54·7	60·9	62·4	60·5	58·4	49·5	44·8	44·7	50·6
1829	31·9	38·4	38·9	44·2	54·4	59·8	60·4	59·3	53·2	47·6	39·3	32·7	46·7
1830	31·3	35·2	45·5	48·5	54·9	56·3	63·4	58·6	54·2	50·5	44·4	35·0	48·1
1831	34·8	41·2	44·2	48·8	52·2	59·5	63·9	63·8	57·3	55·2	42·6	41·8	50·4
1832	36·0	37·1	40·6	46·6	52·1	59·7	61·5	61·6	56·5	51·3	44·1	42·0	49·1
1833	34·3	42·6	..	..	..	..	..	..	..	..	..	..	..

Blackheath Road, 30 feet above Ordnance Datum.

	°	°	°	°	°	°	°	°	°	°	°	°	°
1833	..	..	37·8	45·8	59·0	60·0	61·0	57·8	53·6	50·6	43·4	44·7	..
1834	44·6	39·6	44·3	45·6	56·2	60·9	64·7	62·6	58·5	49·9	44·0	40·5	51·0
1835	38·1	41·6	41·4	46·8	53·1	60·5	64·4	63·3	57·1	48·2	43·5	34·8	49·4
1836	37·9	37·1	44·1	44·3	51·0	61·0	63·1	60·9	53·6	47·3	41·9	39·7	48·5
1837	37·6	40·0	36·1	40·0	48·8	59·9	62·5	61·7	55·2	50·4	40·7	41·2	47·8
1838	28·4	33·4	41·4	42·8	51·6	58·7	60·9	60·7	54·7	49·9	41·0	38·4	46·8
1839	37·1	39·6	39·7	42·7	50·4	59·6	61·2	59·5	55·6	49·1	45·8	39·6	48·3
1840	38·5	37·5	37·7	48·4	54·7	59·7	59·3	..	..	..	..	..	..

Prior Street, 40 feet above Ordnance Datum.

	°	°	°	°	°	°	°	°	°	°	°	°	°
1840	..	..	..	..	..	..	..	63·0	53·2	45·5	43·1	31·9	..
1841	34·1	35·6	46·2	47·3	57·6	56·5	57·9	60·4	58·7	49·3	43·0	39·9	48·9
1842	32·9	40·2	44·5	45·3	54·0	63·5	60·8	66·4	57·3	46·0	42·7	44·7	49·9
1843	39·7	35·6	42·3	47·8	52·3	56·2	60·5	62·8	60·5	47·9	43·7	44·3	49·5
1844	38·6	..	..	..	..	..	..	..	..	..	..	..	..

Rise and Fall of Humidity by Steaming with a Bronchitis Kettle.

TABLE I.—Mean Temperature of the Air at Greenwich deduced from Belville's Observations, September 1811 to June 1856—*continued.*

Hyde Vale, 65 feet above Ordnance Datum.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1844	..	35·2	40·9	50·4	52·1	60·1	61·6	57·9	(57·1)	49·2	43·4	33·2	..
1845	38·9	32·2	35·0	46·1	49·2	60·2	60·3	57·8	53·5	49·1	45·1	41·2	47·4
1846	43·4	43·9	43·3	47·2	54·9	65·4	64·8	63·9	60·3	50·9	45·2	33·1	51·4
1847	35·3	35·9	41·2	44·1	56·7	58·0	64·9	61·8	53·5	52·5	46·3	41·7	49·3
1848	34·5	43·1	43·3	47·2	57·3	58·6	61·9	58·3	55·9	50·4	42·7	43·2	49·7
1849	40·4	42·2	42·2	43·6	54·8	58·7	61·1	61·7	57·6	50·1	43·3	38·3	49·5
1850	33·5	43·4	38·7	48·7	51·2	60·4	61·6	60·2	55·2	46·1	46·1	40·4	48·8
1851	42·0	39·2	42·3	45·0	51·2	59·8	60·5	62·4	55·5	52·4	36·8	40·3	48·9
1852	41·3	40·1	39·6	44·1	51·7	57·3	67·2	62·2	56·3	47·5	48·7	47·3	50·3
1853	41·8	33·0	37·6	46·1	52·0	59·4	61·3	60·1	55·3	50·9	41·6	33·7	47·7
1854	39·2	39·2	43·4	47·7	51·9	57·5	62·4	61·3	57·4	49·4	41·1	41·7	49·3
1855	35·3	29·2	37·5	45·4	49·4	57·9	63·0	62·9	57·0	51·6	41·7	36·1	47·3
1856	39·4	42·2	39·0	47·6	50·8	60·5	..	..	..	..	..	..	..

TABLE II.—Mean Temperature of the Air, Royal Observatory, Greenwich.

Old Series.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1826	..	..	..	..	.	..	..	..	..	..	41·1	41·9	..
1827	34·3	32·5	43·5	48·2	54·2	58·4	64·0	59·5	57·9	52·2	43·2	44·6	49·4
1828	40·3	40·8	43·1	47·7	54·8	60·9	62·2	60·6	58·5	49·7	44·9	44·7	50·7
1829	31·7	38·4	39·0	44·3	54·6	60·1	60·5	59·6	53·3	47·6	39·8	32·5	46·8
1830	31·1	35·3	45·7	48·9	55·2	56·5	63·2	58·8	54·3	50·8	44·5	35·0	48·3
1831	34·8	41·2	44·4	49·0	52·3	59·6	63·5	63·2	56·5	54·9	42·7	41·8	50 3
1832	36·0	37·0	41·1	47·5	52·4	59·8	61·8	..	56·7	51·1	43·5	41·9	..
1833	34·1	42·4	38·3	45·7	58·7	59·4	..	58·2	53·9	50·6	43·4	44·4	..
1834	44·5	39·5	44·4	45·8	..	60·9	64·1	62·3	..	..	43·2	40·6	..
1835	37·6	41·4	41·2	46·8	53·1	60·0	64·1	..	..	..	..	34·7	..
1836	37·4	37·1	..	44·0	51·3	..	63·0	60·2	53·5	47·5	42·1	39·9	..
1837	37·8	40·5	36·1	39·7	48·5	60·1	62·9	61·9	55·7	50·6	40·7	41·3	48·0
1838	28·6	32·4	41·6	42·8	51·6	58·9	60·9	61·0	54·6	49·7	40·5	38·2	46 7
1839	36·9	39·0	39·3	42·8	50·1	59·6	61·2	59·6	55·4	..	45·4	..	..
1840	39·0	37·8	37·6	48·4	..	59·4	59·4	62·9	53·0	45·3	42·9	32·1	..

New Series.

	°	°	°	°	°	°	°	°	°	°	°	°	°
1840	..	..	..	..	..	..	..	..	..	..	..	32·0	..
1841	34·1	35·5	46·4	46·9	57·0	56·3	57·9	60·7	57·8	49·2	43·0	40·4	48·8
1842	32·8	40·3	44·6	45·1	53·3	63·1	60·5	65·5	56·6	45·6	43·0	45·2	49·6
1843	39·7	35·8	42·8	47·5	52·3	56·2	61·1	62·2	60·3	48·3	43·9	44·4	49·5
1844	39·3	35·7	41·4	51·6	53·1	61·1	61·9	58·1	57·5	49·7	43·9	33·3	48·9
1845	38·9	32·7	35·9	46·6	49·5	61·0	60·3	57·8	54·0	50·0	45·7	41·4	47·8
1846	43·6	43·9	43·5	47·2	54·9	65·6	64·8	63·3	60·4	50·7	45·3	33·0	51·3
1847	35·9	35·9	41·7	44·9	56·7	58·1	65·3	62·3	54·2	52·9	47·1	42·6	49·8

TABLE III.—MEAN TEMPERATURE OF THE AIR AT EVERY HOUR OF THE DAY. FROM BELVILLE'S OBSERVATIONS, 1811–1856.

Hour.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1 a.m.	35·5	36·5	38·0	41·6	47·3	53·2	56·4	56·3	52·2	46·9	41·5	38·2	45·3
2 ,,	35·4	36·3	37·7	41·1	46·7	52·5	55·7	55·7	51·6	46·6	41·3	38·1	44·9
3 ,,	35·3	36·1	37·3	40·6	46·1	52·0	55·1	55·2	51·2	46·3	41·2	38·0	44·5
4 ,,	35·2	35·9	37·0	40·2	45·9	51·8	54·8	54·8	50·9	46·1	41·0	37·9	44·3
5 ,,	35·1	35·8	36·8	40·1	46·3	52·5	55·3	54·7	50·7	45·9	40·9	37·9	44·3
6 ,,	35·0	35·7	36·8	40·8	47·8	54·2	56·8	55·6	51·0	45·9	40·8	37·8	44·9
7 ,,	34·9	35·8	37·5	42·7	50·3	56·5	59·0	57·6	52·4	46·4	40·9	37·8	46·0
8 ,,	35·0	36·4	39·1	45·0	52·7	58·8	61·4	59·9	54·8	47·9	41·4	38·0	47·5
9 ,,	35·6	37·6	41·1	47·2	54·9	60·8	63·4	62·1	57·2	49·8	42·4	38·6	49·2
10 ,,	36·6	39·1	43·0	49·1	56·6	62·6	65·2	64·1	59·2	51·7	43·7	39·6	50·9
11 ,,	37·7	40·5	44·5	50·7	58·0	64·1	66·7	65·7	61·0	53·2	45·1	40·6	52·3
Noon.	38·8	41·6	45·7	51·9	59·1	65·3	67·9	67·0	62·2	54·3	46·1	41·3	53·4
1 p.m.	39·3	42·3	46·5	52·9	59·9	66·3	69·0	68·1	63·1	55·0	46·6	41·7	54·2
2 ,,	39·4	42·6	46·8	53·4	60·4	67·0	69·7	68·8	63·6	55·2	46·8	41·8	54·6
3 ,,	39·0	42·4	46·6	53·3	60·3	66·9	69·7	68·7	63·3	54·7	46·3	41·4	54·4
4 ,,	38·3	41·7	45·9	52·4	59·6	66·1	69·0	67·9	62·4	53·8	45·5	40·8	53·6
5 ,,	37·7	40·7	44·7	51·1	58·4	64·7	67·7	66·5	60·9	52·4	44·6	40·1	52·5
6 ,,	37·2	39·8	43·3	49·4	56·8	63·1	66·0	64·7	59·0	51·0	44·0	39·6	51·2
7 ,,	36·8	39·0	42·0	47·6	54·7	61·1	64·0	62·7	57·3	50·0	43·4	39·3	49·8
8 ,,	36·5	38·4	41·0	45·9	52·7	59·1	62·0	60·8	55·9	49·2	43·0	39·0	48·6
9 ,,	36·2	37·9	40·1	44·7	51·0	57·2	60·2	59·4	54·8	48·5	42·6	38·8	47·6
10 ,,	36·0	37·4	39·4	43·7	49·8	55·8	58·9	58·4	54·0	48·0	42·3	38·6	46·9
11 ,,	35·8	37·1	38·9	42·9	48·8	54·7	58·0	57·6	53·2	47·6	42·0	38·5	46·3
Midt.	35·7	36·8	38·4	42·2	48·0	53·9	57·2	56·9	52·7	47·2	41·8	38·4	45·8
	36·6	38·5	41·2	46·3	53·0	59·2	62·0	61·2	56·4	49·7	43·1	39·2	48·9

TABLE IV.—DIFFERENCE FROM THE MEAN TEMPERATURE OF THE AIR AT EVERY HOUR OF THE DAY. FROM BELVILLE'S OBSERVATIONS, 1811–1856.

Hour.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1 a.m.	−1·1	−2·0	−3·2	−4·7	−5·7	−5·9	−5·6	−4·9	−4·2	−2·8	−1·6	−1·0	−3·6
2 ,,	−1·2	−2·2	−3·5	−5·2	−6·3	−6·7	−6·3	−5·5	−4·8	−3·1	−1·8	−1·1	−4·0
3 ,,	−1·3	−2·4	−3·9	−5·7	−6·9	−7·2	−6·9	−6·0	−5·2	−3·4	−1·9	−1·2	−4·4
4 ,,	−1·4	−2·6	−4·2	−6·1	−7·1	−7·4	−7·2	−6·4	−5·5	−3·6	−2·1	−1·3	−4·6
5 ,,	−1·5	−2·7	−4·4	−6·2	−6·7	−6·7	−6·7	−6·5	−5·7	−3·8	−2·2	−1·3	−4·6
6 ,,	−1·6	−2·8	−4·4	−5·5	−5·2	−5·0	−5·2	−5·6	−5·4	−3·8	−2·3	−1·4	−4·0
7 ,,	−1·7	−2·7	−3·7	−3·6	−2·7	−2·7	−3·0	−3·6	−4·0	−3·3	−2·2	−1·4	−2·9
8 ,,	−1·6	−2·1	−2·1	−1·3	−0·3	−0·4	−0·6	−1·3	−1·6	−1·8	−1·7	−1·2	−1·4
9 ,,	−1·0	−0·9	−0·1	+0·9	+1·9	+1·6	+1·4	+0·9	+0·8	+0·1	−0·7	−0·6	+0·3
10 ,,	0·0	+0·6	+1·8	+2·8	+3·6	+3·4	+3·2	+2·9	+2·8	+2·0	+0·6	+0·4	+2·0
11 ,,	+1·1	+2·0	+3·3	+4·4	+5·0	+4·9	+4·7	+4·5	+4·6	+3·5	+2·0	+1·4	+3·4
Noon.	+2·2	+3·1	+4·5	+5·6	+6·1	+6·1	+5·9	+5·8	+5·8	+4·6	+3·0	+2·1	+4·5
1 p.m.	+2·7	+3·8	+5·3	+6·6	+6·9	+7·1	+7·0	+6·9	+6·7	+5·3	+3·5	+2·5	+5·3
2 ,,	+2·8	+4·1	+5·6	+7·1	+7·4	+7·8	+7·7	+7·6	+7·2	+5·5	+3·7	+2·6	+5·7
3 ,,	+2·4	+3·9	+5·4	+7·0	+7·3	+7·7	+7·7	+7·5	+6·9	+5·0	+3·2	+2·2	+5·5
4 ,,	+1·7	+3·2	+4·7	+6·1	+6·6	+6·9	+7·0	+6·7	+6·0	+4·1	+2·4	+1·6	+4·7
5 ,,	+1·1	+2·2	+3·5	+4·8	+5·4	+5·5	+5·7	+5·3	+4·5	+2·7	+1·5	+0·9	+3·6
6 ,,	+0·6	+1·3	+2·1	+3·1	+3·8	+3·9	+4·0	+3·5	+2·6	+1·3	+0·9	+0·4	+2·3
7 ,,	+0·2	+0·5	+0·8	+1·3	+1·7	+1·9	+2·0	+1·5	+0·9	+0·3	+0·3	+0·1	+0·9
8 ,,	−0·1	−0·1	−0·2	−0·4	−0·3	−0·1	0·0	−0·4	−0·5	−0·5	−0·1	−0·2	−0·3
9 ,,	−0·4	−0·6	−1·1	−1·6	−2·0	−2·0	−1·8	−1·8	−1·6	−1·2	−0·5	−0·4	−1·3
10 ,,	−0·6	−1·1	−1·8	−2·6	−3·2	−3·4	−3·1	−2·8	−2·4	−1·7	−0·8	−0·6	−2·0
11 ,,	−0·8	−1·4	−2·3	−3·4	−4·2	−4·5	−4·0	−3·6	−3·2	−2·1	−1·1	−0·7	−2·6
Midt.	−0·9	−1·7	−2·8	−4·1	−5·0	−5·3	−4·8	−4·3	−3·7	−2·5	−1·3	−0·8	−3·1
Range.	4·5	6·9	10·0	13·3	14·5	15·2	14·9	14·1	12·9	9·3	6·0	4·0	10·3

TABLE V.—Monthly and Annual Mean Temperature of the Air at Greenwich. From Belville's Observations, reduced to Sea-Level.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1811	..	..	..	..	...	..	..	..	57·9	55·4	45·0	37·4	..
1812	36·0	41·8	39·1	42·9	54·3	56·9	59·5	59·0	55·5	50·1	40·3	34·2	47·5
1813	34·3	42·6	43·8	47·3	55·9	58·3	60·2	60·4	56·1	48·0	40·3	36·6	48·7
1814	26·9	32·1	37·1	50·2	50·2	55·4	64·2	61·1	56·1	47·7	41·4	41·7	47·0
1815	32·9	44·4	46·0	46·9	56·9	60·7	61·2	62·2	57·9	50·8	38·7	37·0	49·6
1816	36·9	35·1	39·8	44·3	50·2	56·4	58·2	57·7	54·5	50·7	39·1	37·9	46·7
1817	40·1	43·7	41·3	42·9	48·6	60·7	58·9	57·7	57·4	44·1	48·8	37·1	48·4
1818	40·7	36·3	41·2	46·2	52·9	65·0	68·3	63·6	58·3	53·5	48·9	37·4	51·0
1819	40·4	40·3	43·9	48·4	55·7	57·8	62·9	65·6	58·2	49·5	40·9	36·2	49·9
1820	31·9	36·4	40·0	48·9	53·7	57·7	61·2	61·2	54·6	47·8	41·8	40·4	48·0
1821	38·4	35·4	43·3	51·0	50·7	55·1	59·3	63·8	60·8	50·8	48·8	44·8	50·2
1822	39·7	43·8	47·2	47·5	56·7	64·8	63·2	62·6	56·8	53·5	47·5	34·1	51·5
1823	31·2	38·7	40·5	45·0	55·8	56·7	(58 6)	61·1	55·9	48·3	44·1	41·0	(48·1)
1824	38·4	40·0	41·2	45·4	51·2	57·0	64·0	61·8	59·1	50·6	46·9	42·6	49·9
1825	39·2	38·7	39·1	49·2	53·9	58·8	65·2	63·1	60·9	51·6	41·9	41·0	50·2
1826	31·1	42·7	41·9	48·9	51·1	63·7	66·2	66·5	58·2	52·9	40·5	42·7	50·5
1827	34·3	32·0	43·3	48·3	54·3	58·4	63·9	59·4	57·8	52·4	42·9	44·8	49·3
1828	40·5	40·6	43·2	47·7	54·8	61·0	62·5	60·6	58·5	49·6	44·9	44·8	50·7
1829	32·0	38·5	39·0	44·3	54·5	59·9	60·5	59·4	53·3	47·7	39·4	32·8	46·8
1830	31·4	35·3	45·6	48·6	55·0	56·4	63·5	58·7	54·3	50·6	44·5	35·1	48·3
1831	34·9	41·3	44·3	48·9	52·3	59·6	64·0	63·9	57·4	55·3	42·7	41·9	50·5
1832	36·1	37·2	40·7	46·7	52·2	59·8	61·6	61·7	56·6	51·4	44·2	42·1	49·2
1833	34·4	42·7	37·9	45·9	59·1	60·1	61·1	57·9	53·7	50·7	43·5	44·8	49·3
1834	44·7	39·7	44·4	45·7	56·3	61·0	64·8	62·7	58·6	50·0	44·1	40·6	51·0
1835	38·2	41·7	41·5	46·9	53·2	60·6	64·5	63·4	57·2	48·3	43·6	34·9	49·5
1836	38·0	37·2	44·2	44·4	51·1	61·1	63·2	61·0	53·7	47·4	42·0	39·8	48·6
1837	37·7	40·1	36·2	40·1	48·9	60·0	62·6	61·8	55·3	50·5	40·8	41·3	47·9
1838	28·5	33·5	41·5	42·9	51·7	58·8	61·0	60·8	54·8	50·0	41·1	38·5	46·9
1839	37·2	39·7	39·8	42·8	50·5	59·7	61·3	59·6	55·7	49·2	45·9	39·7	48·4
1840	38·6	37·6	37·8	48·5	54·8	59·8	59·4	63·1	53·3	45·6	43·2	32·0	47·8
1841	34·2	35·7	46·3	47·4	57·7	56·6	58·0	60·5	58·8	49·4	43·1	40·0	49·0
1842	33·0	40·3	44·6	45·4	54·1	63·6	60·9	66·5	57·4	46·1	42·8	44·8	50·0
1843	39·8	35·7	42·4	47·9	52·4	56·3	60·6	62·9	60·6	48·0	43·8	41·4	49·6
1844	38·7	35·4	41·1	50·6	52·3	60·3	61·8	58·1	(57·3)	49·4	43·6	33·4	(48·5)
1845	39·1	32·4	35·2	46·3	49·4	60·4	60·5	58·0	53·7	49·3	45·3	41·4	47·6
1846	43·6	44·1	43·5	47·4	55·1	65·6	65·0	64·1	60·5	51·1	45·4	33·3	51·6
1847	35·5	36·1	41·4	44·3	56·9	58·2	65·1	62·0	53·7	52·7	46·5	41·9	49·5
1848	34·7	43·3	43·5	47·4	57·5	58·8	62·1	58·5	56·1	50·6	42·9	43·4	49·9
1849	40·6	42·4	42·4	43·8	55·0	58·9	61·3	61·9	57·8	50·3	43·5	38·5	49·7
1850	33·7	43·6	38·9	48·9	51·4	60·6	61·8	60·4	55·4	46·3	46·3	40·6	49·0
1851	42·2	39·4	42·5	45·2	51·4	60·0	60·7	62·6	55·7	52·6	37·0	40·5	49·1
1852	41·5	40·3	39·8	44·3	51·9	57·5	67·4	62·4	56·5	47·7	48·9	47·5	50·5
1853	42·0	33·2	37·8	46·3	52·2	59·6	61·5	60·3	55·5	51·1	41·8	33·9	47·9
1854	39·4	39·4	43·6	47·9	52·1	57·7	62·6	61·5	57·6	49·6	41·3	41·9	49·5
1855	35·5	29·4	37·7	45·6	49·6	58·1	63·2	63·1	57·2	51·8	41·9	36·3	47·5
1856	39·6	42·4	39·2	47·8	51·0	60·7	..	..	..	..	..	..	..

TABLE VI.—MEAN TEMPERATUUE OF THE AIR, ROYAL OBSERVATORY, JANUARY.

Hour	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1841-1847.
	°	°	°	°	°	°	°	°
1 a.m.	32·7	31·8	38·7	38·2	37·7	42·7	36·4	36·89
2 ,,	32·5	31·4	38·4	38·2	37·3	42·6	36·4	36·69
3 ,,	32·4	31·2	38·3	38·1	37·0	42·4	36·1	36·50
4 ,,	32·3	31·1	38·2	38·1	36·9	42·2	35·7	36·36
5 ,,	32·3	31·1	38·2	38·0	37·0	41·9	35·1	36·28
6 ,,	32·3	31·2	38·1	38·0	37·1	41·7	34·3	36·10
7 ,,	32·3	31·3	38·1	38·0	37·2	41·8	33·4	36·01
8 ,,	32·5	31·6	38·4	38·0	37·5	42·0	33·5	36·21
9 ,,	33·1	32·1	38·8	38·2	38·1	42·4	34·2	36·70
10 ,,	34·3	33·0	39·6	38 8	38·7	43·3	35·5	37·60
11 ,,	35·6	33·8	40·9	40·2	39·7	45·0	36·6	38·83
Noon.	36·8	34·5	41·8	41·5	41·2	45·9	37·6	39·90
1 p.m.	37·3	35·0	42·1	42·1	41·6	46·3	38·0	40·34
2 ,,	37·4	35·2	42·1	42·2	41·7	46·4	38·1	40·44
3 ,,	37·0	35·1	41·8	42·0	41·4	46·1	38·0	40·20
4 ,,	36·2	34·6	41·2	41·3	40·9	45·4	37·5	39·59
5 ,,	35·1	34·0	40·3	40·6	40·1	44·5	36·4	38·71
6 ,,	34·4	33·3	39·8	40·0	39·5	43·9	35·6	38·07
7 ,,	34·2	33·0	39·6	39·4	39·1	43·7	35·1	37·73
8 ,,	34·0	32·9	39·6	38·9	38·9	43·5	35·2	37·57
9 ,,	33·8	32·8	39·6	38·5	38·9	43·3	35·9	37·54
10 ,,	33·7	32·7	39·6	38·3	38·8	43·1	35·9	37·44
11 ,,	33·6	32·5	39·6	38·2	38·4	43·0	35·7	37·29
Midnight.	33·3	32·2	39·4	38·2	38·1	42·9	35·9	37·14
Average	34·1	32·8	39·7	39·3	38·9	43·6	35·9	37·75

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	°	°	°	°	°	°	°	°
1 a.m.	33·5	38·2	34·8	34·2	30·8	42·7	34·2	35·49
2 ,,	33·4	38·2	34·5	34·0	30·5	42·2	34·0	35·26
3 ,,	33·3	38·2	34·2	33·8	30·3	41·7	33·7	35·03
4 ,,	33·3	38·1	34·1	33·4	30·3	41·3	33·5	34·86
5 ,,	33·4	37·9	34·2	32·9	30·3	41·0	33·5	34·74
6 ,,	33·4	37·7	34·1	32·7	30·1	41·0	33·4	34 63
7 ,,	33·4	37·6	34·0	32·6	30·0	41·2	33·3	34·59
8 ,,	33·9	38·3	34·6	33·3	30·6	41·8	33·9	35·20
9 ,,	35·1	39·3	35·4	35·4	32·0	42·6	34·8	36·37
10 ,,	36·4	40·7	36·5	36·9	33·5	43·8	36·3	37·73
11 ,,	37·6	42·3	37·5	37·6	34·8	45·6	37·7	39·00
Noon.	38·6	43·9	38·3	38·4	35·9	46·9	38·8	40·11
1 p.m.	39·4	44·8	38·8	39·2	36·3	47·5	39·6	40·80
2 ,,	39·5	44·9	38·9	39·7	36·5	47·7	39·8	41·00
3 ,,	38·7	44·5	38·7	39·6	36·4	47·5	39·6	40·71
4 ,,	37·8	43·6	37·9	38·7	35·8	46·7	38·7	39·89
5 ,,	37·2	42·2	36·8	37·3	34·6	45·5	37·7	38·76
6 ,,	36·3	41·2	36·1	36·4	33·7	44·8	36·8	37·90
7 ,,	35·2	40·2	35·7	35·6	33·0	44·2	36·1	37·14
8 ,,	34·8	39·6	35·3	35·3	32·3	43·8	35·8	36·70
9 ,,	34·7	39·4	34·9	35·2	31·9	43·5	35·5	36·44
10 ,,	34·5	39·0	34·7	34·9	31·8	43·5	35·1	36·21
11 ,,	34·3	38·6	34·5	34·5	31·8	43·4	34·6	35·96
Midnight.	34·0	38·4	34·6	34·3	31·5	43·2	34·3	35·76
Average	35·5	40·3	35·8	35·7	32·7	43·9	35·9	37·10

TABLE VI.—MEAN TEMPERATURE OF THE AIR, ROYAL OBSERVATORY, MARCH.

Hour.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	18 1-1847.
	°	°	°	°	°	°	°	°
1 a.m.	42·8	42·6	39·7	38·5	33·2	40·1	37·8	39·24
2 ,,	42·6	42·2	39·4	38·2	33·0	39·8	37·4	38·94
3 ,,	42·2	41·7	39·2	38·1	32·7	39·5	37·3	38·67
4 ,,	41·8	41·2	38·9	38·0	32·5	39·3	37·1	38·40
5 ,,	41·1	40·9	38·7	37·8	32·7	39·1	36·6	38·13
6 ,,	40·9	40·8	38·7	37·7	32·9	39·0	36·6	38·09
7 ,,	41·3	41·1	39·0	38·4	33·2	39·9	37·3	38·60
8 ,,	42·8	42·0	40·3	39·8	34·0	41·6	38·7	39·89
9 ,,	45·6	44·1	42·8	41·5	36·0	43·5	41·6	42·16
10 ,,	48·5	45·7	45·0	43·3	37·7	45·5	44·6	44·33
11 ,,	51·8	46·7	46·5	44·7	39·0	47·2	46·7	46·09
Noon.	53·1	48·0	47·7	45·8	40·0	48·3	47·8	47·24
1 p.m.	53·5	49·4	48·4	46·4	40·5	49·0	48·6	47·97
2 ,,	53·7	49·8	48·4	46·6	40·5	49·3	48·8	48·16
3 ,,	53·6	49·5	47·8	46·2	40·1	49·2	48·6	47·86
4 ,,	52·9	48·6	47·0	45·4	39·8	48·5	47·7	47·13
5 ,,	50·8	47·6	46·0	44·1	39·5	47·1	46·0	45·87
6 ,,	48·5	46·4	44·8	42·7	38·3	45·4	44·2	44·33
7 ,,	46·4	44·9	43·1	41·6	36·5	43·8	41·9	42·60
8 ,,	45·2	44·1	42·0	40·7	35·1	42·8	40·6	41·50
9 ,,	44·7	43·7	41·3	40·1	34·5	42·3	39·7	40·90
10 ,,	44·1	43·4	40·9	39·6	33·9	41·7	39·2	40·40
11 ,,	43·4	43·1	40·6	39·4	33·4	41·1	38·8	39·97
Midnight.	43·0	42·8	40·2	39·1	33·2	40·6	38·4	39·61
Average.	46·4	44·6	42·8	41·4	35·9	43·5	41·7	42·34
				APRIL.				
	°	°	°	°	°	°	°	°
1 a.m.	42·4	40·0	42·5	44·8	41·1	42·8	40·5	42·01
2 ,,	42·1	39·8	42·1	44·0	40·7	42·5	40·1	41·61
3 ,,	41·7	39·5	41·8	43·3	40·4	42·3	39·7	41·24
4 ,,	41·3	39·3	41·6	42·6	40·1	42·1	39·2	40·89
5 ,,	41·0	39·2	41·4	42·2	39·9	41·9	39·0	40·66
6 ,,	41·4	39·7	42·1	43·4	40·4	42·5	39·7	41·31
7 ,,	43·6	41·7	43·6	46·4	42·3	44·4	41·3	43·33
8 ,,	46·1	44·5	45·9	49·7	44·5	46·7	43·5	45·84
9 ,,	48·4	46·5	48·3	52·9	47·1	48·5	46·0	48·24
10 ,,	50·2	48·5	50·6	55·9	50·0	50·1	48·2	50·50
11 ,,	51·6	50·1	52·1	58·3	52·4	51·5	50·2	52·31
Noon.	52·6	51·5	53·4	60·3	54·0	52·3	51·1	53·60
1 p.m.	53·2	52·6	54·6	61·8	55·0	52·6	51·5	54·47
2 ,,	53·4	52·8	54·9	62·2	55·1	52·8	51·6	54·69
3 ,,	53·2	52·5	54·5	61·8	54·1	52·7	51·3	54·30
4 ,,	52·5	51·2	53·6	60·5	53·0	52·1	50·5	53·34
5 ,,	51·5	49·8	52·3	58·9	52·1	51·0	49·3	52·13
6 ,,	50·0	48·0	50·6	56·5	50·6	49·6	47·5	50·40
7 ,,	47·9	45·8	48·4	53·3	47·8	48·1	45·7	48·14
8 ,,	46·2	44·1	46·9	50·8	45·5	46·9	44·3	46·39
9 ,,	45·3	43·0	45·9	49·0	44·2	45·9	43·2	45·21
10 ,,	44·4	41·9	45·0	47·8	43·2	45·1	42·2	44·23
11 ,,	43·6	41·0	44·0	46·9	42·4	44·3	41·5	43·39
Midnight.	43·0	40·4	43·1	45·9	41·7	43·5	40·9	42·64
Average.	46·9	45·1	47·5	51·6	46·6	47·2	44·9	47·12

TABLE VI.—MEAN TEMPERATURE OF THE AIR, ROYAL OBSERVATORY, MAY.

Hour.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1841-1847.
	°	°	°	°	°	°	°	°
1 a.m.	50·4	46·7	47·0	46·3	44·8	48·3	50·2	47·67
2 ,,	50·0	46·5	46·9	45·7	44·6	47·8	49·7	47·31
3 ,,	49·5	46·2	46·7	45·1	44·4	47·3	49·3	46·93
4 ,,	49·3	46·1	46·6	44·8	44·2	47·2	49·0	46·74
5 ,,	49·8	46·5	47·0	44·8	44·3	47·6	49·3	47·04
6 ,,	51·6	47·8	48·6	46·2	45·2	49·1	51·1	48·51
7 ,,	54·6	50·2	51·2	49·4	46·9	52·4	54·0	51·24
8 ,,	57·6	52·8	53·4	52·7	49·0	55·6	56·5	53·94
9 ,,	60·0	55·3	55·1	55·5	50·9	57·9	58·7	56·20
10 ,,	61·5	57·6	56·4	57·7	52·5	59·7	60·7	58·01
11 ,,	62·8	59·5	57·1	59·4	53·9	61·0	62·6	59·47
Noon.	64·2	60·8	57·7	60·8	55·0	62·1	64·0	60·66
1 p.m.	65·6	61·4	58·2	61·9	55·7	62·8	64·6	61·46
2 ,,	65·5	61·4	58·1	62·3	55·9	62·8	64·8	61·54
3 ,,	64·5	60·5	57·6	62·1	55·6	62·4	64·5	61·03
4 ,,	63·4	59·5	57·0	60·9	54·9	61·4	63·7	60·11
5 ,,	62·2	58·4	56·3	59·3	53·8	60·2	62·2	58·91
6 ,,	60·6	56·9	55·1	57·3	52·2	58·3	60·3	57·24
7 ,,	58·1	55·1	53·2	54·9	50·4	56·0	58·3	55·14
8 ,,	56·0	53·0	51·4	52·6	48·8	53·9	56·2	53·13
9 ,,	54·5	51·2	50·0	50·3	47·4	52·5	54·3	51·46
10 ,,	53·4	49·7	48·8	48·9	46·4	51·4	53·3	50·27
11 ,,	52·4	48·6	47·9	48·1	45·5	50·4	52·4	49·33
Midnight.	51·4	47·6	47·3	47·2	45·0	49·4	51·3	48·46
Average	57·0	53·3	52·3	53·1	49·5	54·9	56·7	53·83
				JUNE.				
	°	°	°	°	°	°	°	°
1 a.m.	50·2	54·2	50·5	53·5	54·2	56·6	51·9	53·01
2 ,,	49·6	53·5	50·0	53·0	53·8	55·9	51·5	52·47
3 ,,	49·0	52·8	49·7	52·5	53·3	55·4	51·0	51·96
4 ,,	48·8	52·8	49·7	52·4	53·1	55·3	50·9	51·86
5 ,,	49·2	53·6	50·4	53·0	53·6	56·0	51·5	52·47
6 ,,	50·9	56·2	51·9	54·6	55·6	58·2	53·3	54·39
7 ,,	53·6	60·2	54·1	57·6	58·3	62·2	55·7	57·39
8 ,,	56·8	64·1	56·3	60·8	60·9	66·5	58·0	60·49
9 ,,	59·1	67·0	58·2	63·4	63·2	69·8	60·2	62·99
10 ,,	60·3	69·0	59·8	65·6	65·2	72·3	62·4	64·94
11 ,,	60·9	70·5	61·0	67·2	66·9	73·9	64·4	66·40
Noon.	61·6	71·9	62·1	69·2	68·0	75·4	65·3	67·64
1 p.m.	62·8	72·9	63·0	70·7	68·5	76·1	65·6	68·51
2 ,,	63·4	73·1	63·5	71·0	68·9	76·2	65·6	68·81
3 ,,	63·3	72·8	63·3	70·4	69·1	75·5	65·5	68·56
4 ,,	62·9	71·8	62·4	69·3	68·6	74·4	64·7	67·73
5 ,,	62·3	70·2	61·1	67·8	67·0	72·7	63·5	66·37
6 ,,	61·0	68·2	59·5	65·8	65·0	70·7	61·7	64·56
7 ,,	59·0	65·6	57·8	63·4	62·9	68·0	59·5	62·31
8 ,,	56·8	62·8	55·9	60·6	60·6	64·7	57·3	59·81
9 ,,	54·7	60·3	54·0	58·1	58·4	62·1	55·4	57·57
10 ,,	53·2	58·4	52·6	56·5	57·0	60·4	54·1	56·03
11 ,,	51·9	57·0	51·8	55·4	56·0	58·8	53·1	54·86
Midnight.	50·9	55·7	51·2	54·4	55·1	57·7	52·5	53·93
Average	56·3	63·1	56·2	61·1	61·0	65·6	58·1	60·21

TABLE VI.—MEAN TEMPERATURE OF THE AIR, ROYAL OBSERVATORY, JULY.

Hour.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1841–1847.
	°	°	°	°	°	°	°	°
1 a.m.	53·0	54·5	55·6	56·0	55·3	58·0	57·2	55·66
2 „	52·6	53·9	55·1	55·4	54·9	57·4	56·6	55·13
3 „	52·3	53·3	54·7	54·9	54·4	57·1	56·2	54·70
4 „	52·1	53·0	54·5	54·8	54·2	56·9	56·0	54·50
5 „	52·5	53·5	54·7	55·0	54·5	57·2	56·1	54·79
6 „	53·9	55·0	55·9	56·6	55·7	59·1	58·0	56·31
7 „	56·0	57·8	58·0	58·9	57·9	62·0	61·4	58·86
8 „	57·9	60·6	60·7	61·8	60·2	64·6	64·2	61·43
9 „	59·4	62·6	62·9	64·4	61·9	67·1	66·7	63·57
10 „	61·2	64·3	64·6	66·6	63·6	69·2	69·0	65·50
11 „	63·0	65·8	66·1	67·9	65·2	71·2	71·2	67·20
Noon.	63·8	67·0	66·8	68·5	66·2	72·4	73·1	68·26
1 p.m.	63·9	67·4	67·1	68·7	66·8	73·0	74·6	68·79
2 „	63·7	67·7	67·4	68·8	67·0	72·9	75·2	68·96
3 „	62·9	67·7	68·0	68·9	66·9	72·3	75·3	68·86
4 „	62·5	67·1	67·5	68·4	66·3	71·4	74·4	68·23
5 „	62·3	65·9	66·2	67·4	65·2	70·4	73·0	67·20
6 „	61·4	64·4	64·8	65·8	63·6	69·1	70·9	65·71
7 „	59·7	62·4	63·0	63·5	61·7	66·9	68·4	63·66
8 „	58·0	60·3	61·1	61·4	59·6	64·7	65·6	61·53
9 „	56·3	58·7	59·3	59·6	58·1	62·6	63·5	59·73
10 „	54·9	57·3	57·9	58·5	57·0	61·0	61·5	58·30
11 „	54·0	55·9	57·1	57·8	56·3	59·8	60·0	57·27
Midnight.	53·5	55·1	56·4	57·0	55·7	58·9	58·5	56·44
Average.	57·9	60·5	61·1	61·9	60·3	64·8	65·3	61·69

AUGUST.

	°	°	°	°	°	°	°	°
1 a.m.	56·0	58·4	56·6	53·2	52·7	58·2	56·0	55·87
2 „	55·7	57·9	56·3	52·7	52·3	57·9	55·5	55·47
3 „	55·4	57·4	56·1	52·2	51·9	57·7	55·0	55·10
4 „	55·0	57·0	56·0	51·6	51·6	57·6	54·6	54·77
5 „	55·1	57·0	56·0	51·2	51·7	57·6	54·7	54·76
6 „	55·9	58·3	56·8	51·9	52·9	58·3	55·9	55·71
7 „	57·9	61·0	59·0	54·4	54·9	60·2	58·1	57·93
8 „	59·9	64·1	61·8	57·1	57·1	62·5	60·7	60·46
9 „	62·0	67·3	64·3	59·9	59·6	64·8	63·5	63·06
10 „	63·8	70·1	66·1	62·1	61·5	66·8	66·2	65·23
11 „	65·2	72·5	67·7	63·2	62·9	68·7	68·3	66·93
Noon.	66·6	74·4	68·7	64·1	63·9	69·7	69·8	68·17
1 p.m.	68·1	75·6	69·1	64·8	64·7	70·3	70·6	69·03
2 „	68·5	75·7	69·2	64·9	64·8	70·6	71·2	69·27
3 „	68·0	75·2	69·1	64·6	64·6	70·5	71·4	69·06
4 „	66·9	74·0	68·7	63·9	63·9	69·7	70·2	68·19
5 „	65·4	72·5	67·8	63·1	62·9	68·1	68·1	66·84
6 „	63·4	70·0	65·9	61·5	61·2	66·2	66·0	64·86
7 „	61·2	66·9	63·2	59·4	58·8	64·1	63·7	62·47
8 „	59·2	64·1	60·8	57·6	56·9	62·3	61·9	60·40
9 „	58·1	62·3	59·5	56·4	55·4	61·0	60·3	59·00
10 „	57·2	61·0	58·4	55·5	54·4	60·0	59·1	57·94
11 „	56·6	60·0	57·6	54·7	53·8	59·1	58·1	57·13
Midnight.	56·3	59·1	57·1	54·0	53·2	58·5	57·1	56·47
Average	60·7	65·5	62·2	58·1	57·8	63·3	62·3	61·42

TABLE VI.—Mean Temperature of the Air, Royal Observatory, September.

Hour.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1841-1847.
	°	°	°	°	°	°	°	°
1 a.m.	54·6	52·9	54·7	53·3	49·3	54·7	49·5	52·71
2 ,,	54·1	52·7	54·4	53·0	48·8	54·4	49·0	52·34
3 ,,	53·5	52·5	54·1	52·6	48·2	54·1	48·6	51·94
4 ,,	53·1	52·3	54·0	52·3	47·8	53·7	48·3	51·64
5 ,,	52·9	52·1	54·0	52·1	47·8	53·4	48·1	51·49
6 ,,	53·3	52·0	54·3	52·0	48·8	53·4	48·2	51·71
7 ,,	54·5	53·2	55·4	53·0	50·3	55·2	49·6	53·03
8 ,,	56·5	55·2	57·7	54·9	52·4	58·2	52·0	55·27
9 ,,	58·2	57·6	61·0	57·4	55·3	61·9	55·3	58·10
10 ,,	59·6	59·3	64·2	60·4	57·6	65·4	58·1	60·66
11 ,,	60·9	60·8	66·6	62·2	58·9	67·7	59·8	62·41
Noon.	62·2	61·8	68·3	63·7	59·9	68·9	60·9	63·67
1 p.m.	63·5	62·2	69·1	64·9	60·7	69·5	61·5	64·49
2 ,,	64·3	62·0	69·2	65·3	61·0	69·6	61·3	64·67
3 ,,	64·3	61·3	68·6	65·2	60·7	69·2	60·7	64·29
4 ,,	63·4	60·5	67·2	64·2	59·6	67·8	59·6	63·19
5 ,,	62·0	59·4	65·2	62·2	58·2	65·8	58·2	61·57
6 ,,	60·1	58·3	63·0	59·9	56·5	63·2	56·5	59·64
7 ,,	58·2	56·9	60·7	57·7	54·7	60·6	55·0	57·69
8 ,,	56·8	55·9	59·2	56·4	53·4	58·8	53·9	56·34
9 ,,	56·1	55·2	58·1	55·6	52·6	57·4	53·0	55·43
10 ,,	55·5	54·6	57·0	54·9	51·7	56·4	52·0	54·59
11 ,,	55·1	54·0	56·1	54·3	50·9	55·4	51·1	53·84
Midnight.	54·7	53·5	55·3	53·7	50·1	54·9	50·2	53·20
Average	57·8	56·6	60·3	57·5	54·0	60·4	54·2	57·25
			October.					
	°	°	°	°	°	°	°	°
1 a.m.	46·9	42·1	45·5	46·2	46·3	48·5	49·8	46·47
2 ,,	46·7	41·7	45·4	46·1	46·1	48·5	49·6	46·30
3 ,,	46·6	41·2	45·3	46·1	46·4	48·6	49·5	46·24
4 ,,	46·6	40·9	45·1	45·9	46·4	48·6	49·4	46·13
5 ,,	46·7	40·9	44·9	45·5	46.2	48·6	49·1	45·99
6 ,,	46·8	41·0	45·0	45·4	46·3	48·6	49·1	46·03
7 ,,	47·1	41·3	45·7	45·8	47·0	48·8	49·5	46·46
8 ,,	47·8	42·0	46·8	47·3	48·2	49·6	50·9	47·51
9 ,,	49·5	44·4	48·4	49·8	50·2	51·4	53·0	49·53
10 ,,	51·4	47·2	50·3	51·8	52·4	52·9	55·4	51·63
11 ,,	53·0	49·3	52·0	53·4	54·4	53·9	57·8	53·40
Noon.	53·9	50·8	53·0	54·5	55·6	54·6	58·8	54·46
1 p.m.	54·1	51·5	53·3	55·2	56·1	55·0	59·2	54·91
2 ,,	53·9	51·7	53·4	55·4	56·3	54·9	58·8	54·91
3 ,,	53·2	51·4	53·0	55·0	56·0	54·4	57·9	54·41
4 ,,	51·8	50·4	52·2	54·1	54·6	53·3	56·6	53·29
5 ,,	50·4	49·0	50·5	52·6	52·4	52·0	54·9	51·69
6 ,,	49·1	47·9	49·0	51·1	50·9	50·8	53·4	50·31
7 ,,	48·3	47·1	48·2	49·9	49·6	50·2	52·4	49·39
8 ,,	48·0	46·2	47·5	49·4	48·7	49·7	51·7	48·74
9 ,,	47·8	45·2	46·8	49·0	48·1	49·3	51·1	48·19
10 ,,	47·6	44·3	46·1	48·6	47·6	48·8	50·6	47·66
11 ,,	47·3	43·3	46·0	47·9	47·3	48·3	50·3	47·20
Midnight.	47·1	42·7	45·5	47·0	46·9	48·1	50·0	46·76
Average	49·2	45·6	48·3	49·7	50·0	50·7	52·9	49·48

TABLE VI.—MEAN TEMPERATURE OF THE AIR, ROYAL OBSERVATORY, NOVEMBER.

Hour.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1841–1847.
	°	°	°	°	°	°	°	°
1 a.m.	41·5	41·6	42·6	42·7	43·6	44·2	45·6	43·11
2 ,,	41·4	41·5	42·5	42·7	43·5	44·1	45·4	43·01
3 ,,	41·3	41·6	42·3	42·6	43·3	44·0	45·2	42·90
4 ,,	41·1	41·7	42·2	42·5	43·2	43·8	45·1	42·80
5 ,,	40·9	41·8	42·2	42·3	43·0	43·7	44·9	42·69
6 ,,	40·7	41·8	42·1	42·2	42·9	43·6	44·9	42·60
7 ,,	40·9	41·7	41·9	42·1	43·1	43·5	45·0	42·60
8 ,,	41·4	42·1	42·3	42·4	43·6	43·6	45·6	43·00
9 ,,	42·3	43·2	43·2	43·2	44·9	44·6	46·7	44·01
10 ,,	43·3	44·3	44·6	44·3	46·8	45·8	48·1	45·31
11 ,,	44·6	45·5	46·0	45·3	48·6	46·9	49·2	46·59
Noon.	45·8	45·9	47·0	46·1	50·0	47·7	50·0	47·50
1 p.m.	46·7	46·0	47·4	46·7	50·7	48·4	50·6	48·07
2 ,,	47·0	45·9	47·5	46·9	50·7	48·5	50·7	48·17
3 ,,	46·6	45·5	47·0	46·4	49·6	48·0	50·0	47·59
4 ,,	45·6	44·5	45·9	45·8	48·4	47·1	48·9	46·60
5 ,,	44·5	43·4	44·7	45·2	47·1	46·1	47·9	45·56
6 ,,	43·5	42·8	44·0	44·6	46·4	45·6	47·3	44·89
7 ,,	42·9	42·4	43·6	44·1	45·8	45·2	46·9	44·41
8 ,,	42·5	42·0	43·2	43·7	45·2	44·8	46·6	44·00
9 ,,	42·2	41·7	42·9	43·3	44·7	44·4	46·5	43·67
10 ,,	42·0	41·5	42·8	43·0	44·3	44·2	46·3	43·44
11 ,,	41·8	41·7	42·9	42·9	43·9	44·1	46·1	43·34
Midnight.	41·7	41·7	42·8	42·8	43·7	44·1	45·9	43·24
Average.	43·0	43·0	43·9	43·9	45·7	45·3	47·1	44·55

DECEMBER.

Hour.	1840.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1840–1847.
	°	°	°	°	°	°	°	°	c
1 a.m.	30·9	39·8	44·0	43·8	32·0	40·2	31·8	41·4	37·99
2 ,,	30·8	39·8	44·2	43·6	31·9	39·8	31·6	41·5	37·90
3 ,,	30·7	39·5	44·3	43·5	31·9	39·7	31·4	41·5	37·81
4 ,,	30·7	39·4	44·5	43·3	31·9	39 8	31·3	41·6	37·81
5 ,,	30·8	39·3	44·6	43·0	32·0	39·9	31·4	41·9	37·86
6 ,,	30·7	39·2	44·7	42·8	32·2	39·9	31·4	41·9	37·85
7 ,,	30·6	39·1	44·8	42·6	32·4	39·8	31·5	42·0	37·85
8 ,,	30·8	39·3	44·8	42·7	32·7	39·9	31·6	42·1	37·99
9 ,,	31·7	39·8	44·9	43·1	33·0	40·5	31·9	42·4	38·41
10 ,,	32·8	40·8	45·2	44·1	33·7	41·6	32·8	43·0	39·25
11 ,,	33·9	42·0	46·3	45·1	34·5	42·7	34·0	43·8	40·29
Noon.	34·7	42·6	47·3	46·0	35·0	43·5	35·2	44·7	41·12
1 p.m.	35·1	42·8	47·8	46·6	35·1	44·1	36·0	45·3	41·60
2 ,,	35·1	42·7	47·7	46·5	35·0	44·2	36·1	45·2	41·56
3 ,,	34·6	42·2	47·2	46·1	34·8	43·7	35·7	44·4	41·09
4 ,,	33·7	41·7	46·5	45·7	34·5	42·8	35·1	43·5	40·44
5 ,,	32·6	41·0	45·7	45·2	34·1	42·0	34·3	42·9	39·73
6 ,,	31·8	40·5	45·2	45·0	33·8	41·7	33·6	42·5	39·26
7 ,,	31·4	40·3	44·9	44·9	33·7	41·5	33·3	42·3	39·04
8 ,,	31·2	40·1	44·6	44·8	33·6	41·4	33·0	42·0	38·84
9 ,,	31·1	39·9	44·2	44·5	33·3	41·2	32·8	41·5	38·56
10 ,,	31·1	39·7	43·9	44·3	33·0	41·0	32·5	41·3	38·35
11 ,,	31·2	39·5	43·6	44·1	32·7	40·9	32·4	41·2	38·20
Midnight.	31·1	39·6	43·6	43·9	32·4	40·6	32·1	41·3	38·08
Average.	32·0	40·4	45·2	44·4	33·3	41·4	33·0	42·6	39·04

TABLE VI.—Mean Temperature of the Air, Royal Observatory, January.

Hour	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1841-1847.
	°	°	°	°	°	°	°	°
1 a.m.	32·7	31·8	38·7	38·2	37·7	42·7	36·4	36·89
2 ,,	32·5	31·4	38·4	38·2	37·3	42·6	36·4	36·69
3 ,,	32·4	31·2	38·3	38·1	37·0	42·4	36·1	36·50
4 ,,	32·3	31·1	38·2	38·1	36·9	42·2	35·7	36·36
5 ,,	32·3	31·1	38·2	38·0	37·0	41·9	35·1	36·28
6 ,,	32·3	31·2	38·1	38·0	37·1	41·7	34·3	36·10
7 ,,	32·3	31·3	38·1	38·0	37·2	41·8	33·4	36·01
8 ,,	32·5	31·6	38·4	38·0	37·5	42·0	33·5	36·21
9 ,,	33·1	32·1	38·8	38·2	38·1	42·4	34·2	36·70
10 ,,	34·3	33·0	39·6	38 8	38·7	43·3	35·5	37·60
11 ,,	35·6	33·8	40·9	40·2	39·7	45·0	36·6	38·83
Noon.	36·8	34·5	41·8	41·5	41·2	45·9	37·6	39·90
1 p.m.	37·3	35·0	42·1	42·1	41·6	46·3	38·0	40·34
2 ,,	37·4	35·2	42·1	42·2	41·7	46·4	38·1	40·44
3 ,,	37·0	35·1	41·8	42·0	41·4	46·1	38·0	40·20
4 ,,	36·2	34·6	41·2	41·3	40·9	45·4	37·5	39·59
5 ,,	35·1	34·0	40·3	40·6	40·1	44·5	36·4	38·71
6 ,,	34·4	33·3	39·8	40·0	39·5	43·9	35·6	38·07
7 ,,	34·2	33·0	39·6	39·4	39·1	43·7	35·1	37·73
8 ,,	34·0	32·9	39·6	38·9	38·9	43·5	35·2	37·57
9 ,,	33·8	32·8	39·6	38·5	38·9	43·3	35·9	37·54
10 ,,	33·7	32·7	39·6	38·3	38·8	43·1	35·9	37·44
11 ,,	33·6	32·5	39·6	38·2	38·4	43·0	35·7	37·29
Midnight.	33·3	32·2	39·4	38·2	38·1	42·9	35·9	37·14
Average	34·1	32·8	39·7	39·3	38·9	43·6	35·9	37·75

FEBRUARY.

	°	°	°	°	°	°	°	°
1 a.m.	33·5	38·2	34·8	34·2	30·8	42·7	34·2	35·49
2 ,,	33·4	38·2	34·5	34·0	30·5	42·2	34·0	35·26
3 ,,	33·3	38·2	34·2	33·8	30·3	41·7	33·7	35·03
4 ,,	33·3	38·1	34·1	33·4	30·3	41·3	33·5	34·86
5 ,,	33·4	37·9	34·2	32·9	30·3	41·0	33·5	34·74
6 ,,	33·4	37·7	34·1	32·7	30·1	41·0	33·4	34 63
7 ,,	33·4	37·6	34·0	32·6	30·0	41·2	33·3	34·59
8 ,,	33·9	38·3	34·6	33·3	30·6	41·8	33·9	35·20
9 ,,	35·1	39·3	35·4	35·4	32·0	42·6	34·8	36·37
10 ,,	36·4	40·7	36·5	36·9	33·5	43·8	36·3	37·73
11 ,,	37·6	42·3	37·5	37·6	34·8	45·6	37·7	39·00
Noon.	38·6	43·9	38·3	38·4	35·9	46·9	38·8	40·11
1 p.m.	39·4	44·8	38·8	39·2	36·3	47·5	39·6	40·80
2 ,,	39·5	44·9	38·9	39·7	36·5	47·7	39·8	41·00
3 ,,	38·7	44·5	38·7	39·6	36·4	47·5	39·6	40·71
4 ,,	37·8	43·6	37·9	38·7	35·8	46·7	38·7	39·89
5 ,,	37·2	42·2	36·8	37·3	34·6	45·5	37·7	38·76
6 ,,	36·3	41·2	36·1	36·4	33·7	44·8	36·8	37·90
7 ,,	35·2	40·2	35·7	35·6	33·0	44·2	36·1	37·14
8 ,,	34·8	39·6	35·3	35·3	32·3	43·8	35·8	36·70
9 ,,	34·7	39·4	34·9	35·2	31·9	43·5	35·5	36·44
10 ,,	34·5	39·0	34·7	34·9	31·8	43·5	35·1	36·21
11 ,,	34·3	38·6	34·5	34·5	31·8	43·4	34·6	35·96
Midnight.	34·0	38·4	34·6	34·3	31·5	43·2	34·3	35·76
Average	35·5	40·3	35·8	35·7	32·7	43·9	35·9	37·10

TABLE VI.—MEAN TEMPERATURE OF THE AIR, ROYAL OBSERVATORY, MARCH.

Hour.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	18 1-1847.
	°	°	°	°	°	°	°	°
1 a.m.	42·8	42·6	39·7	38·5	33·2	40·1	37·8	39·24
2 ,,	42·6	42·2	39·4	38·2	33·0	39·8	37·4	38·94
3 ,,	42·2	41·7	39·2	38·1	32·7	39·5	37·3	38·67
4 ,,	41·8	41·2	38·9	38·0	32·5	39·3	37·1	38·40
5 ,,	41·1	40·9	38·7	37·8	32·7	39·1	36·6	38·13
6 ,,	40·9	40·8	38·7	37·7	32·9	39·0	36·6	38·09
7 ,,	41·3	41·1	39·0	38·4	33·2	39·9	37·3	38·60
8 ,,	42·8	42·0	40·3	39·8	34·0	41·6	38·7	39·89
9 ,,	45·6	44·1	42·8	41·5	36·0	43·5	41·6	42·16
10 ,,	48·5	45·7	45·0	43·3	37·7	45·5	44·6	44·33
11 ,,	51·8	46·7	46 5	44·7	39·0	47·2	46·7	46·09
Noon.	53·1	48·0	47·7	45·8	40·0	48·3	47·8	47·24
1 p.m.	53·5	49·4	48·4	46·4	40·5	49·0	48·6	47·97
2 ,,	53·7	49·8	48·4	46·6	40·5	49·3	48·8	48·16
3 ,,	53·6	49·5	47·8	46·2	40·1	49·2	48·6	47·86
4 ,,	52·9	48·6	47·0	45·4	39·8	48·5	47·7	47·13
5 ,,	50·8	47·6	46·0	44·1	39·5	47·1	46·0	45·87
6 ,,	48·5	46·4	44·8	42·7	38·3	45·4	44·2	44·33
7 ,,	46·4	44·9	43·1	41·6	36·5	43·8	41·9	42·60
8 ,,	45·2	44·1	42·0	40·7	35·1	42·8	40·6	41·50
9 ,,	44·7	43·7	41·3	40·1	34·5	42·3	39·7	40·90
10 ,,	44·1	43·4	40·9	39·6	33·9	41·7	39·2	40·40
11 ,,	43·4	43·1	40·6	39·4	33·4	41·1	38·8	39·97
Midnight.	43·0	42·8	40·2	39·1	33·2	40·6	38·4	39·61
Average.	46·4	44·6	42·8	41·4	35·9	43·5	41·7	42·34
				APRIL.				
	°	°	°	°	°	°	°	°
1 a.m.	42·4	40·0	42·5	44·8	41·1	42·8	40·5	42·01
2 ,,	42·1	39·8	42·1	44·0	40·7	42·5	40·1	41·61
3 ,,	41·7	39·5	41·8	43·3	40·4	42·3	39·7	41·24
4 ,,	41·3	39·3	41·6	42·6	40·1	42·1	39·2	40·89
5 ,,	41·0	39·2	41·4	42·2	39·9	41·9	39·0	40·66
6 ,,	41·4	39·7	42·1	43·4	40·4	42·5	39·7	41·31
7 ,,	43·6	41·7	43·6	46·4	42·3	44·4	41·3	43·33
8 ,,	46·1	44·5	45·9	49·7	44·5	46·7	43·5	45·84
9 ,,	48·4	46·5	48·3	52·9	47·1	48·5	46·0	48·24
10 ,,	50·2	48·5	50·6	55·9	50·0	50·1	48·2	50·50
11 ,,	51·6	50·1	52·1	58·3	52·4	51·5	50·2	52·31
Noon.	52·6	51·5	53·4	60·3	54·0	52·3	51·1	53·60
1 p.m.	53·2	52·6	54·6	61·8	55·0	52·6	51·5	54·47
2 ,,	53·4	52·8	54·9	62·2	55·1	52·8	51·6	54·69
3 ,,	53·2	52·5	54·5	61·8	54·1	52·7	51·3	54·30
4 ,,	52·5	51·2	53·6	60·5	53·0	52·1	50·5	53·34
5 ,,	51·5	49·8	52·3	58·9	52·1	51·0	49·3	52·13
6 ,,	50·0	48·0	50·6	56·5	50·6	49·6	47·5	50·40
7 ,,	47·9	45·8	48·4	53·3	47·8	48·1	45·7	48·14
8 ,,	46·2	44·1	46·9	50·8	45·5	46 9	44·3	46·39
9 ,,	45·3	43·0	45·9	49·0	44·2	45·9	43·2	45·21
10 ,,	44·4	41·9	45·0	47·8	43·2	45·1	42·2	44·23
11 ,,	43·6	41·0	44·0	46·9	42·4	44·3	41·5	43·39
Midnight.	43·0	40·4	43·1	45·9	41·7	43·5	40·9	42·64
Average.	46·9	45·1	47·5	51·6	46·6	47·2	44·9	47·12

TABLE VI.—MEAN TEMPERATURE OF THE AIR, ROYAL OBSERVATORY, MAY.

Hour.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1841-1847.
	°	°	°	°	°	°	°	°
1 a.m.	50·4	46·7	47·0	46·3	44·8	48·3	50·2	47·67
2 ,,	50·0	46·5	46·9	45·7	44·6	47·8	49·7	47·31
3 ,,	49·5	46·2	46·7	45·1	44·4	47·3	49·3	46·93
4 ,,	49·3	46·1	46·6	44·8	44·2	47·2	49·0	46·74
5 ,,	49·8	46·5	47·0	44·8	44·3	47·6	49·3	47·04
6 ,,	51·6	47·8	48·6	46·2	45·2	49·1	51·1	48·51
7 ,,	54·6	50·2	51·2	49·4	46·9	52·4	54·0	51·24
8 ,,	57·6	52·8	53·4	52·7	49·0	55·6	56·5	53·94
9 ,,	60·0	55·3	55·1	55·5	50·9	57·9	58·7	56·20
10 ,,	61·5	57·6	56·4	57·7	52·5	59·7	60·7	58·01
11 ,,	62·8	59·5	57·1	59·4	53·9	61·0	62·6	59·47
Noon.	64·2	60·8	57·7	60·8	55·0	62·1	64·0	60·66
1 p.m.	65·6	61·4	58·2	61·9	55·7	62·8	64·6	61·46
2 ,,	65·5	61·4	58·1	62·3	55·9	62·8	64·8	61·54
3 ,,	64·5	60·5	57·6	62·1	55·6	62·4	64·5	61·03
4 ,,	63·4	59·5	57·0	60·9	54·9	61·4	63·7	60·11
5 ,,	62·2	58·4	56·3	59·3	53·8	60·2	62·2	58·91
6 ,,	60·6	56·9	55·1	57·3	52·2	58·3	60·3	57·24
7 ,,	58·1	55·1	53·2	54·9	50·4	56·0	58·3	55·14
8 ,,	56·0	53·0	51·4	52·6	48·8	53·9	56·2	53·13
9 ,,	54·5	51·2	50·0	50·3	47·4	52·5	54·3	51·46
10 ,,	53·4	49·7	48·8	48·9	46·4	51·4	53·3	50·27
11 ,,	52·4	48·6	47·9	48·1	45·5	50·4	52·4	49·33
Midnight.	51·4	47·6	47·3	47·2	45·0	49·4	51·3	48·46
Average	57·0	53·3	52·3	53·1	49·5	54·9	56·7	53·83
				JUNE.				
	°	°	°	°	°	°	°	°
1 a.m.	50·2	54·2	50·5	53·5	54·2	56·6	51·9	53·01
2 ,,	49·6	53·5	50·0	53·0	53·8	55·9	51·5	52·47
3 ,,	49·0	52·8	49·7	52·5	53·3	55·4	51·0	51·96
4 ,,	48·8	52·8	49·7	52·4	53·1	55·3	50·9	51·86
5 ,,	49·2	53·6	50·4	53·0	53·6	56·0	51·5	52·47
6 ,,	50·9	56·2	51·9	54·6	55·6	58·2	53·3	54·39
7 ,,	53·6	60·2	54·1	57·6	58·3	62·2	55·7	57·39
8 ,,	56·8	64·1	56·3	60·8	60·9	66·5	58·0	60·49
9 ,,	59·1	67·0	58·2	63·4	63·2	69·8	60·2	62·99
10 ,,	60·3	69·0	59·8	65·6	65·2	72·3	62·4	64·94
11 ,,	60·9	70·5	61·0	67·2	66·9	73·9	64·4	66·40
Noon.	61·6	71·9	62·1	69·2	68·0	75·4	65·3	67·64
1 p.m.	62·8	72·9	63·0	70·7	68·5	76·1	65·6	68·51
2 ,,	63·4	73·1	63·5	71·0	68·9	76·2	65·6	68·81
3 ,,	63·3	72·8	63·3	70·4	69·1	75·5	65·5	68·56
4 ,,	62·9	71·8	62·4	69·3	68·6	74·4	64·7	67·73
5 ,,	62·3	70·2	61·1	67·8	67·0	72·7	63·5	66·37
6 ,,	61·0	68·2	59·5	65·8	65·0	70·7	61·7	64·56
7 ,,	59·0	65·6	57·8	63·4	62·9	68·0	59·5	62·31
8 ,,	56·8	62·8	55·9	60·6	60·6	64·7	57·3	59·81
9 ,,	54·7	60·3	54·0	58·1	58·4	62·1	55·4	57·57
10 ,,	53·2	58·4	52·6	56·5	57·0	60·4	54·1	56·03
11 ,,	51·9	57·0	51·8	55·4	56·0	58·8	53·1	54·86
Midnight.	50·9	55·7	51·2	54·4	55·1	57·7	52·5	53·93
Average	56·3	63·1	56·2	61·1	61·0	65·6	58·1	60·21

TABLE VI.—MEAN TEMPERATURE OF THE AIR, ROYAL OBSERVATORY, JULY.

Hour.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1841–1847.
	°	°	°	°	°	°	°	°
1 a.m.	53·0	54·5	55·6	56·0	55·3	58·0	57·2	55·66
2 „	52·6	53·9	55·1	55·4	54·9	57·4	56·6	55·13
3 „	52·3	53·3	54·7	54·9	54·4	57·1	56·2	54·70
4 „	52·1	53·0	54·5	54·8	54·2	56·9	56·0	54·50
5 „	52·5	53·5	54·7	55·0	54·5	57·2	56·1	54·79
6 „	53·9	55·0	55·9	56·6	55·7	59·1	58·0	56·31
7 „	56·0	57·8	58·0	58·9	57·9	62·0	61·4	58·86
8 „	57·9	60·6	60·7	61·8	60·2	64·6	64·2	61·43
9 „	59·4	62·6	62·9	64·4	61·9	67·1	66·7	63·57
10 „	61·2	64·3	64·6	66·6	63·6	69·2	69·0	65·50
11 „	63·0	65·8	66·1	67·9	65·2	71·2	71·2	67·20
Noon.	63·8	67·0	66·8	68·5	66·2	72·4	73·1	68·26
1 p.m.	63·9	67·4	67·1	68·7	66·8	73·0	74·6	68·79
2 „	63·7	67·7	67·4	68·8	67·0	72·9	75·2	68·96
3 „	62·9	67·7	68·0	68·9	66·9	72·3	75·3	68·86
4 „	62·5	67·1	67·5	68·4	66·3	71·4	74·4	68·23
5 „	62·3	65·9	66·2	67·4	65·2	70·4	73·0	67·20
6 „	61·4	64·4	64·8	65·8	63·6	69·1	70·9	65·71
7 „	59·7	62·4	63·0	63·5	61·7	66·9	68·4	63·66
8 „	58·0	60·3	61·1	61·4	59·6	64·7	65·6	61·53
9 „	56·3	58·7	59·3	59·6	58·1	62·6	63·5	59·73
10 „	54·9	57·3	57·9	58·5	57·0	61·0	61·5	58·30
11 „	54·0	55·9	57·1	57·8	56·3	59·8	60·0	57·27
Midnight.	53·5	55·1	56·4	57·0	55·7	58·9	58·5	56·44
Average.	57·9	60·5	61·1	61·9	60·3	64·8	65·3	61·69

AUGUST.

	°	°	°	°	°	°	°	°
1 a.m.	56·0	58·4	56·6	53·2	52·7	58·2	56·0	55·87
2 „	55·7	57·9	56·3	52·7	52·3	57·9	55·5	55·47
3 „	55·4	57·4	56·1	52·2	51·9	57·7	55·0	55·10
4 „	55·0	57·0	56·0	51·6	51·6	57·6	54·6	54·77
5 „	55·1	57·0	56·0	51·2	51·7	57·6	54·7	54·76
6 „	55·9	58·3	56·8	51·9	52·9	58·3	55·9	55·71
7 „	57·9	61·0	59·0	54·4	54·9	60·2	58·1	57·93
8 „	59·9	64·1	61·8	57·1	57·1	62·5	60·7	60·46
9 „	62·0	67·3	64·3	59·9	59·6	64·8	63·5	63·06
10 „	63·8	70·1	66·1	62·1	61·5	66·8	66·2	65·23
11 „	65·2	72·5	67·7	63·2	62·9	68·7	68·3	66·93
Noon.	66·6	74·4	68·7	64·1	63·9	69·7	69·8	68·17
1 p.m.	68·1	75·6	69·1	64·8	64·7	70·3	70·6	69·03
2 „	68·5	75·7	69·2	64·9	64·8	70·6	71·2	69·27
3 „	68·0	75·2	69·1	64·6	64·6	70·5	71·4	69·06
4 „	66·9	74·0	68·7	63·9	63·9	69·7	70·2	68·19
5 „	65·4	72·5	67·8	63·1	62·9	68·1	68·1	66·84
6 „	63·4	70·0	65·9	61·5	61·2	66·2	66·0	64·86
7 „	61·2	66·9	63·2	59·4	58·8	64·1	63·7	62·47
8 „	59·2	64·1	60·8	57·6	56·9	62·3	61·9	60·40
9 „	58·1	62·3	59·5	56·4	55·4	61·0	60·3	59·00
10 „	57·2	61·0	58·4	55·5	54·4	60·0	59·1	57·94
11 „	56·6	60·0	57·6	54·7	53·8	59·1	58·1	57·13
Midnight.	56·3	59·1	57·1	54·0	53·2	58·5	57·1	56·47
Average	60·7	65·5	62·2	58·1	57·8	63·3	62·3	61·42

TABLE VI.—Mean Temperature of the Air, Royal Observatory, September.

Hour.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1841-1847.
	°	°	°	°	°	°	°	°
1 a.m.	54·6	52·9	54·7	53·3	49·3	54·7	49·5	52·71
2 ,,	54·1	52·7	54·4	53·0	48·8	54·4	49·0	52·34
3 ,,	53·5	52·5	54·1	52·6	48·2	54·1	48·6	51·94
4 ,,	53·1	52·3	54·0	52·3	47·8	53·7	48·3	51·64
5 ,,	52·9	52·1	54·0	52·1	47·8	53·4	48·1	51·49
6 ,,	53·3	52·0	54·3	52·0	48·8	53·4	48·2	51·71
7 ,,	54·5	53·2	55·4	53·0	50·3	55·2	49·6	53·03
8 ,,	56·5	55·2	57·7	54·9	52·4	58·2	52·0	55·27
9 ,,	58·2	57·6	61·0	57·4	55·3	61·9	55·3	58·10
10 ,,	59·6	59·3	64·2	60·4	57·6	65·4	58·1	60·66
11 ,,	60·9	60·8	66·6	62·2	58·9	67·7	59·8	62·41
Noon.	62·2	61·8	68·3	63·7	59·9	68·9	60·9	63·67
1 p.m.	63·5	62·2	69·1	64·9	60·7	69·5	61·5	64·49
2 ,,	64·3	62·0	69·2	65·3	61·0	69·6	61·3	64·67
3 ,,	64·3	61·3	68·6	65·2	60·7	69·2	60·7	64·29
4 ,,	63·4	60·5	67·2	64·2	59·6	67·8	59·6	63·19
5 ,,	62·0	59·4	65·2	62·2	58·2	65·8	58·2	61·57
6 ,,	60·1	58·3	63·0	59·9	56·5	63·2	56·5	59·64
7 ,,	58·2	56·9	60·7	57·7	54·7	60·6	55·0	57·69
8 ,,	56·8	55·9	59·2	56·4	53·4	58·8	53·9	56·34
9 ,,	56·1	55·2	58·1	55·6	52·6	57·4	53·0	55·43
10 ,,	55·5	54·6	57·0	54·9	51·7	56·4	52·0	54·59
11 ,,	55·1	54·0	56·1	54·3	50·9	55·4	51·1	53·84
Midnight.	54·7	53·5	55·3	53·7	50·1	54·9	50·2	53·20
Average	57·8	56·6	60·3	57·5	54·0	60·4	54·2	57·25
			October.					
	°	°	°	°	°	°	°	°
1 a.m.	46·9	42·1	45·5	46·2	46·3	48·5	49·8	46·47
2 ,,	46·7	41·7	45·4	46·1	46·1	48·5	49·6	46·30
3 ,,	46·6	41·2	45·3	46·1	46·4	48·6	49·5	46·24
4 ,,	46·6	40·9	45·1	45·9	46·4	48·6	49·4	46·13
5 ,,	46·7	40·9	44·9	45·5	46.2	48·6	49·1	45·99
6 ,,	46·8	41·0	45·0	45·4	46·3	48·6	49·1	46·03
7 ,,	47·1	41·3	45·7	45·8	47·0	48·8	49·5	46·46
8 ,,	47·8	42·0	46·8	47·3	48·2	49·6	50·9	47·51
9 ,,	49·5	44·4	48·4	49·8	50·2	51·4	53·0	49·53
10 ,,	51·4	47·2	50·3	51·8	52·4	52·9	55·4	51·63
11 ,,	53·0	49·3	52·0	53·4	54·4	53·9	57·8	53·40
Noon.	53·9	50·8	53·0	54·5	55·6	54·6	58·8	54·46
1 p.m.	54·1	51·5	53·3	55·2	56·1	55·0	59·2	54·91
2 ,,	53·9	51·7	53·4	55·4	56·3	54·9	58·8	54·91
3 ,,	53·2	51·4	53·0	55·0	56·0	54·4	57·9	54·41
4 ,,	51·8	50·4	52·2	54·1	54·6	53·3	56·6	53·29
5 ,,	50·4	49·0	50·5	52·6	52·4	52·0	54·9	51·69
6 ,,	49·1	47·9	49·0	51·1	50·9	50·8	53·4	50·31
7 ,,	48·3	47·1	48·2	49·9	49·6	50·2	52·4	49·39
8 ,,	48·0	46·2	47·5	49·4	48·7	49·7	51·7	48·74
9 ,,	47·8	45·2	46·8	49·0	48·1	49·3	51·1	48·19
10 ,,	47·6	44·3	46·1	48·6	47·6	48·8	50·6	47·66
11 ,,	47·3	43·3	46·0	47·9	47·3	48·3	50·3	47·20
Midnight.	47·1	42·7	45·5	47·0	46·9	48·1	50·0	46·76
Average	49·2	45·6	48·3	49·7	50·0	50·7	52·9	49·48

TABLE VI.—MEAN TEMPERATURE OF THE AIR, ROYAL OBSERVATORY, NOVEMBER.

Hour.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1841–1847.
	°	°	°	°	°	°	°	°
1 a.m.	41·5	41·6	42·6	42·7	43·6	44·2	45·6	43·11
2 ,,	41·4	41·5	42·5	42·7	43·5	44·1	45·4	43·01
3 ,,	41·3	41·6	42·3	42·6	43·3	44·0	45·2	42·90
4 ,,	41·1	41·7	42·2	42·5	43·2	43·8	45·1	42·80
5 ,,	40·9	41·8	42·2	42·3	43·0	43·7	44·9	42·69
6 ,,	40·7	41·8	42·1	42·2	42·9	43·6	44·9	42·60
7 ,,	40·9	41·7	41·9	42·1	43·1	43·5	45·0	42·60
8 ,,	41·4	42·1	42·3	42·4	43·6	43·6	45·6	43·00
9 ,,	42·3	43·2	43·2	43·2	44·9	44·6	46·7	44·01
10 ,,	43·3	44·3	44·6	44·3	46·8	45·8	48·1	45·31
11 ,,	44·6	45·5	46·0	45·3	48·6	46·9	49·2	46·59
Noon.	45·8	45·9	47·0	46·1	50·0	47·7	50·0	47·50
1 p.m.	46·7	46·0	47·4	46·7	50·7	48·4	50·6	48·07
2 ,,	47·0	45·9	47·5	46·9	50·7	48·5	50·7	48·17
3 ,,	46·6	45·5	47·0	46·4	49·6	48·0	50·0	47·59
4 ,,	45·6	44·5	45·9	45·8	48·4	47·1	48·9	46·60
5 ,,	44·5	43·4	44·7	45·2	47·1	46·1	47·9	45·56
6 ,,	43·5	42·8	44·0	44·6	46·4	45·6	47·3	44·89
7 ,,	42·9	42·4	43·6	44·1	45·8	45·2	46·9	44·41
8 ,,	42·5	42·0	43·2	43·7	45·2	44·8	46·6	44·00
9 ,,	42·2	41·7	42·9	43·3	44·7	44·4	46·5	43·67
10 ,,	42·0	41·5	42·8	43·0	44·3	44·2	46·3	43·44
11 ,,	41·8	41·7	42·9	42·9	43·9	44·1	46·1	43·34
Midnight.	41·7	41·7	42·8	42·8	43·7	44·1	45·9	43·24
Average.	43·0	43·0	43·9	43·9	45·7	45·3	47·1	44·55

DECEMBER.

Hour.	1840.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1840–1847.
	°	°	°	°	°	°	°	°	c
1 a.m.	30·9	39·8	44·0	43·8	32·0	40·2	31·8	41·4	37·99
2 ,,	30·8	39·8	44·2	43·6	31·9	39·8	31·6	41·5	37·90
3 ,,	30·7	39·5	44·3	43·5	31·9	39·7	31·4	41·5	37·81
4 ,,	30·7	39·4	44·5	43·3	31·9	39 8	31·3	41·6	37·81
5 ,,	30·8	39·3	44·6	43·0	32·0	39·9	31·4	41·9	37·86
6 ,,	30·7	39·2	44·7	42·8	32·2	39·9	31·4	41·9	37·85
7 ,,	30·6	39·1	44·8	42·6	32·4	39·8	31·5	42·0	37·85
8 ,,	30·8	39·3	44·8	42·7	32·7	39·9	31·6	42·1	37·99
9 ,,	31·7	39·8	44·9	43·1	33·0	40·5	31·9	42·4	38·41
10 ,,	32·8	40·8	45·2	44·1	33·7	41·6	32·8	43·0	39·25
11 ,,	33·9	42·0	46·3	45·1	34·5	42·7	34·0	43·8	40·29
Noon.	34·7	42·6	47·3	46·0	35·0	43·5	35·2	44·7	41·12
1 p.m.	35·1	42·8	47·8	46·6	35·1	44·1	36·0	45·3	41·60
2 ,,	35·1	42·7	47·7	46·5	35·0	44·2	36·1	45·2	41·56
3 ,,	34·6	42·2	47·2	46·1	34·8	43·7	35·7	44·4	41·09
4 ,,	33·7	41·7	46·5	45·7	34·5	42·8	35·1	43·5	40·44
5 ,,	32·6	41·0	45·7	45·2	34·1	42·0	34·3	42·9	39·73
6 ,,	31·8	40·5	45·2	45·0	33·8	41·7	33·6	42·5	39·26
7 ,,	31·4	40·3	44·9	44·9	33·7	41·5	33·3	42·3	39·04
8 ,,	31·2	40·1	44·6	44·8	33·6	41·4	33·0	42·0	38·84
9 ,,	31·1	39·9	44·2	44·5	33·3	41·2	32·8	41·5	38·56
10 ,,	31·1	39·7	43·9	44·3	33·0	41·0	32·5	41·3	38·35
11 ,,	31·2	39·5	43·6	44·1	32·7	40·9	32·4	41·2	38·20
Midnight.	31·1	39·6	43·6	43·9	32·4	40·6	32·1	41·3	38·08
Average.	32·0	40·4	45·2	44·4	33·3	41·4	33·0	42·6	39·04

TABLE VII.—ANNUAL MEAN TEMPERATURE OF THE AIR AT EVERY HOUR OF THE DAY.

Hour.	Royal Observatory, Old Series, Sept. 1811 to Oct. 1822.	Park Row, Nov. 1822 to July 1825.	Park Terrace, Aug. 1825 to Feb. 1833.	Blackheath Road, March 1833 to July 1840.	Prior Street, Aug. 1840 to Jan. 1844.	Hyde Vale, Feb. 1844 to June 1856.	Royal Observatory, New Series, Jan. 1841 to Dec. 1847.	Royal Observatory, Photographic Records, 1849-1868, and 1880, 1881, 1882.
	°	°	°	°	°	°	°	°
1 a.m.	44·9	45·8	45·7	44·8	45·7	45·6	45·6	46·0
2 ,,	44·5	45·5	45·2	44·4	45·2	45·2	45·3	45·7
3 ,,	44·3	45·2	44·8	44·0	44·8	44·8	45·0	45·4
4 ,,	44·1	45·0	44·5	43·7	44·5	44·5	44·8	45·2
5 ,,	44·1	45·1	44·6	43·8	44·4	44·5	44·8	45·3
6 ,,	44·6	45·5	45·1	44·5	44·8	45·0	45·4	45·9
7 ,,	45·6	46·5	46·3	45·9	45·6	46·1	46·6	47·0
8 ,,	47·1	47·9	47·9	47·6	47·0	47·7	48·2	48·5
9 ,,	48·8	49·5	49·7	49·4	48·9	49·3	50·0	50·4
10 ,,	50·5	51·0	51·3	51·0	50·7	50·9	51·8	52·0
11 ,,	51·9	52·4	52·8	52·6	52·4	52·3	53·3	53·5
Noon.	53·0	53·4	54·0	53·7	53·6	53·3	54·4	54·7
1 p m.	53·8	54·2	54·8	54·4	54·5	54·1	55·1	55·3
2 ,,	54·1	54·7	55·2	54·7	55·0	54·5	55·3	55·5
3 ,,	53·8	54·5	55·0	54·5	54·8	54·4	54·9	55·1
4 ,,	53·0	53·8	54·2	53·6	54·0	53·6	54·1	54·2
5 ,,	51·9	52·6	53·1	52·4	52·9	52·5	52·9	53·0
6 ,,	50·6	51·3	51·8	51·1	51·6	51·3	51·5	51·6
7 ,,	49·2	50·0	50·4	49·6	50·2	50·0	50·1	50·2
8 ,,	48·0	48·9	49·2	48·4	49·0	48·9	48·8	48·9
9 ,,	47·0	48·0	48·2	47·3	48·0	48·0	47·9	47·9
10 ,,	46·2	47·2	47·4	46·5	47·2	47·2	47·2	47·2
11 ,,	45·7	46·7	46·8	45·8	46·7	46·6	46·6	46·7
Midnight.	45·2	46·2	46·2	45·3	46·2	46·1	46·1	46·3
Average	48·4	49·2	49·3	48·7	49·1	49·0	49·4	49·6
Reduced to Sea Level	49·0	49·3	49·4	48·8	49·2	49·2	50·0	50·2

TABLE VIII.—DIFFERENCE FROM THE ANNUAL MEAN TEMPERATURE OF THE AIR AT EVERY HOUR OF THE DAY.

	°	°	°	°	°	°	°	°
1 a.m.	−3·5	−3·4	−3·6	−3·9	−3·4	−3·4	−3·8	− 3·6
2 ,,	−3·9	−3·7	−4·1	−4·3	−3·9	−3·8	−4·1	− 3·9
3 ,,	−4·1	−4·0	−4·5	−4·7	−4·3	−4·2	−4·4	− 4·2
4 ,,	−4·3	−4·2	−4·8	−5·0	−4·6	−4·5	−4·6	− 4·4
5 ,,	−4·3	−4·1	−4·7	−4·9	−4·7	−4·5	−4·6	− 4·3
6 ,,	−3·8	−3·7	−4·2	−4·2	−4·3	−4·0	−4·0	− 3·7
7 ,,	−2·8	−2·7	−3·0	−2·8	−3·5	−2·9	−2·8	− 2·6
8 ,,	−1·3	−1·3	−1·4	−1·1	−2·1	−1·3	−1·2	− 1·1
9 ,,	+0·4	+0·3	+0·4	+0·7	−0·2	+0·3	+0·6	+ 0·8
10 ,,	+2·1	+1·8	+2·0	+2·3	+1·6	+1·9	+2·4	+ 2·4
11 ,,	+3·5	+3·2	+3·5	+3·9	+3·3	+3·3	+3·9	+ 3·9
Noon.	+4·6	+4·2	+4·7	+5·0	+4·5	+4·3	+5·0	+ 5·1
1 p.m.	+5·4	+5·0	+5·5	+5·7	+5·4	+5·1	+5·7	+ 5·7
2 ,,	+5·7	+5·5	+5·9	+6·0	+5·9	+5·5	+5·9	+ 5·9
3 ,,	+5·4	+5·3	+5·7	+5·8	+5·7	+5·4	+5·5	+ 5·5
4 ,,	+4·6	+4·6	+4·9	+4·9	+4·9	+4·6	+4·7	+ 4·6
5 ,,	+3·5	+3·4	+3·8	+3·7	+3·8	+3·5	+3·5	+ 3·4
6 ,,	+2·2	+2·1	+2·5	+2·4	+2·5	+2·3	+2·1	+ 2·0
7 ,,	+0·8	+0·8	+1·1	+0·9	+1·1	+1·0	+0·7	+ 0·6
8 ,,	−0·4	−0·3	−0·1	−0·3	−0·1	−0·1	−0·6	− 0·7
9 ,,	−1·4	−1·2	−1·1	−1·4	−1·1	−1·0	−1·5	− 1·7
10 ,,	−2·2	−2·0	−1·9	−2·2	−1·9	−1·8	−2·2	− 2·4
11 ,,	−2·7	−2·5	−2·5	−2·9	−2·4	−2·4	−2·8	− 2·9
Midnight.	−3·2	−3·0	−3·1	−3·4	−2·9	−2·9	−3·3	− 3·3
Range	10·0	9·7	10·7	11·0	10·6	10·0	10·5	10·3

TABLE IX.—Mean Temperature of the Air at every Hour of the Day and Difference from the Mean.

The Royal Observatory (Old Series) and Park Terrace, and the Royal Observatory (New Series) and Prior Street and Hyde Vale compared.

Hour.	Royal Observatory, Old Series, November 1826 to February 1831.	Park Terrace, November 1826 to February 1831.	Royal Observatory, below Park Terrace.	Royal Observatory, Old Series, Diff. from Annual Mean.	Park Terrace, Diff. from Annual Mean.	Royal Observatory, New Series, December 1840 to January 1844.	Prior Street, December 1840 to January 1844.	Royal Observatory, below Prior Street.	Royal Observatory, New Series, Diff. from Annual Mean.	Prior Street, Diff. from Annual Mean.	Royal Observatory, New Series, February 1844 to December 1847.	Hyde Vale, February 1844 to December 1847.	Royal Observatory, below Hyde Vale.	Royal Observatory, New Series, Diff. from Annual Mean.	Hyde Vale, Diff. from Annual Mean.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1 a.m.	45·5	45·2	+0·3	−3·4	−3·6	45·5	45·9	−0·4	−3·7	−3·3	45·5	45·6	−0·1	−3·9	−3·5
2 ,,	45·1	44·7	+0·4	−3·8	−4·1	45·2	45·4	−0·2	−4·0	−3·8	45·2	45·2	0·0	−4·2	−3·9
3 ,,	44·8	44·3	+0·5	−4·1	−4·5	44·9	45·0	−0·1	−4·3	−4·2	44·9	44·8	+0·1	−4·5	−4·3
4 ,,	44·6	44·1	+0·5	−4·3	−4·7	44·7	44·7	0·0	−4·5	−4·5	44·7	44·5	+0·2	−4·7	−4·6
5 ,,	44·6	44·1	+0·5	−4·3	−4·7	44·8	44·6	+0·2	−4·4	−4·6	44·7	44·5	+0·2	−4·7	−4·6
6 ,,	45·1	44·7	+0·4	−3·8	−4·1	45·3	45·0	+0·3	−3·9	−4·2	45·2	45·0	+0·2	−4·2	−4·1
7 ,,	46·2	45·9	+0·3	−2·7	−2·9	46·5	45·8	+0·7	−2·7	−3·4	46·5	46·1	+0·4	−2·9	−3·0
8 ,,	47·6	47·5	+0·1	−1·3	−1·3	48·0	47·2	+0·8	−1·2	−2·0	48·2	47·7	+0·5	−1·2	−1·4
9 ,,	49·1	49·1	0·0	+0·2	+0·3	49·8	49·0	+0·8	+0·6	−0·2	50·1	49·4	+0·7	+0·7	+0·3
10 ,,	50·7	50·7	0·0	+1·8	+1·9	51·5	50·9	+0·6	+2·3	+1·7	52·0	50·9	+1·1	+2·6	+1·8
11 ,,	52·0	52·1	−0·1	+3·1	+3·3	52·9	52·5	+0·4	+3·7	+3·3	53·6	52·3	+1·3	+4·2	+3·2
Noon	53·1	53·2	−0·1	+4·2	+4·4	54·1	53·8	+0·3	+4·9	+4·6	54·6	53·3	+1·3	+5·2	+4·2
1 p.m.	53·8	54·1	−0·3	+4·9	+5·3	54·7	54·7	0·0	+5·5	+5·5	55·3	54·1	+1·2	+5·9	+5·0
2 ,,	54·2	54·5	−0·3	+5·3	+5·7	54·9	55·1	−0·2	+5·7	+5·9	55·4	54·6	+0·8	+6·0	+5·5
3 ,,	54·1	54·3	−0·2	+5·2	+5·5	54·5	54·9	−0·4	+5·3	+5·7	55·1	54·5	+0·6	+5·7	+5·4
4 ,,	53·5	53·5	0·0	+4·6	+4·7	53·6	54·2	−0·6	+4·4	+5·0	54·2	53·9	+0·3	+4·8	+4·8
5 ,,	52·4	52·4	0·0	+3·5	+3·6	52·5	53·1	−0·6	+3·3	+3·9	53·0	52·7	+0·3	+3·6	+3·6
6 ,,	51·1	51·1	0·0	+2·2	+2·3	51·2	51·7	−0·5	+2·0	+2·5	51·6	51·5	+0·1	+2·2	+2·4
7 ,,	49·8	49·8	0·0	+0·9	+1·0	49·8	50·4	−0·6	+0·6	+1·2	50·1	50·2	−0·1	+0·7	+1·1
8 ,,	48·6	48·6	0·0	−0·3	−0·2	48·6	49·2	−0·6	−0·6	0·0	48·9	49·0	−0·1	−0·5	−0·1
9 ,,	47·7	47·6	+0·1	−1·2	−1·2	47·7	48·2	−0·5	−1·5	−1·0	47·9	48·0	−0·1	−1·5	−1·1
10 ,,	47·0	46·9	+0·1	−1·9	−1·9	46·9	47·4	−0·5	−2·3	−1·8	47·2	47·2	0·0	−2·2	−1·9
11 ,,	46·4	46·2	+0·2	−2·5	−2·6	46·4	46·8	−0·4	−2·8	−2·4	46·6	46·6	0·0	−2·8	−2·5
Midnight	45·9	45·7	+0·2	−3·0	−3·1	45·9	46·3	−0·4	−3·3	−2·9	46·0	46·1	−0·1	−3·4	−3·0
	48·9	48·8	+0·1	9·6	10·4	49·2	49·2	0·0	10·2	10·5	49·4	49·1	+0·3	10·7	10·1

TABLE X.—MEAN MONTHLY TEMPERATURE OF THE AIR. COMPARISON BETWEEN (1) THE ROYAL OBSERVATORY (OLD SERIES) AND PARK TERRACE. (2) THE ROYAL OBSERVATORY (NEW SERIES) AND PRIOR STREET AND HYDE VALE.

Month.	November 1826 to February 1831.		December 1840 to January 1844.		February 1844 to December 1847.	
	Royal Observatory, Old Series.	Park Terrace.	Royal Observatory, New Series.	Prior Street.	Royal Observatory, New Series.	Hyde Vale.
	°	°	°	°	°	°
January	34·4	34·5	36·5	36·3	39·5	39·2
February	37·6	37·4	37·2	37·2	37·0	36·8
March	42·8	42·7	44·6	44·3	40·6	40·1
April	47·3	47·1	46·5	46·8	47·6	46·9
May	54·7	54·6	54·2	54·6	53·5	53·2
June	59·0	58·9	58·6	58·7	61·4	60·9
July	62·5	62·5	59·8	59·8	63·1	62·9
August	59·6	59·4	62·8	63·2	60·4	60·4
September	56·0	55·9	58·2	58·8	56·2	55·7
October	50·1	50·0	47·7	47·8	50·8	50·4
November	42·7	42·3	43·3	43·1	45·5	45·0
December	39·8	39·9	40·5	40·2	37·6	37·3
Year	48·9	48·8	49·2	49·2	49·4	49·1

DISCUSSION.

Mr. EATON said he wished to express his great obligations to the President (Mr. Ellis), who not only had seen to the correctness of the transcript of the "Old Series" of temperature observations, but who had also conducted him to each of Mr. Belville's stations, so that he might become personally acquainted with the precise locality. He was also indebted to Mr. Henry S. Tabor for kind assistance in preparing Table VI.

THE PRESIDENT (Mr. Ellis) said that the number of pages to which Mr. Eaton's paper extended afforded no indication of the amount of work necessary for its production, as he had in various ways good opportunity of knowing. He had superintended the preparation for Mr. Eaton of a complete copy of the old Observatory meteorological registers of temperature extending from 1807 to the year 1840, and had done so with great pleasure, being well assured of the excellent use that Mr. Eaton would make thereof.

Dr. TRIPE said he could not but express his admiration at the amount of work done, and of the manner in which Mr. Eaton had carried out his task. Mr. Park Harrison some years ago endeavoured to investigate the question of the influence of the moon on temperature, but was brought to a standstill for want of a continuous and reliable series of observations previous to 1841. The Greenwich observations for the subsequent seven years were to a great extent vitiated by the gaps which occurred in the registers, especially between Saturday evening and Monday morning. If Mr. Eaton's research led to no other result than to show (as it most clearly did) that the climate of our country is not changing, as some would have us believe, that was a good point gained. There is no doubt that the information embodied in this paper will be of great benefit to any persons who in future years may work in a similar direction. Mr. Eaton had deposited in the Society's Library the whole of the documents from which the

tables given in the Paper had been compiled, so that they could be referred to by any Fellow who might desire to use them.

Mr. MAWLEY considered the Paper a model for the guidance of those who might make investigations of a similar character in the future. Mr. Glaisher had gone over the same ground in his Tables of Greenwich Mean Temperatures,[1] but not having adopted the same exhaustive treatment as the author in his examination of past records, the values there given were necessarily less reliable. This was to be regretted, as no tables of the kind had hitherto been so frequently referred to as these. The thermometers at the Royal Observatory were placed on a Glaisher stand, and consequently the shade temperatures indicated by them were higher in the daytime and lower at night than they should be. Moreover, the general exposure was somewhat confined, and there was not sufficient grass beneath and around the thermometer-stand, which still further injuriously affected their indications. It had been thought that the maxima readings in very hot weather were seriously affected by the glare from the surrounding buildings; but on taking the absolute maxima at Greenwich for several years and comparing them with those given by his own Glaisher stand at Addiscombe, he had found the readings at the Royal Observatory, even under these extreme conditions, to be only from 1°·5 to 3°·5 higher. For six years he had a Glaisher stand and a Stevenson screen side by side at Addiscombe. The average excess of the maxima temperatures on the former over those in the latter, in the three summer months during this period, amounted to 1°·3, while the mean minima were 0°·7 lower on the Glaisher stand than in the Stevenson screen. He was very pleased to find that a Stevenson screen had at last been set up at the Royal Observatory, but he nevertheless thought that the Glaisher stand observations should not, at all events for some years to come, be discontinued, as it was the long series of readings from this stand which made the Greenwich temperatures so valuable.

Mr. SYMONS said that he fully agreed with all that had been said regarding the value and thoroughness of the work done by Mr. Eaton. With reference to Mr. Mawley's comparison between Addiscombe and Greenwich, he thought that 3°·5 was a serious difference; more than that due to difference of stands. It would appear that the white buildings in the vicinity of the meteorological grounds of the Royal Observatory reflected heat. At any rate the surroundings of the Greenwich instruments were not satisfactory, and he believed that a minus correction would have to be applied to the summer maximum temperatures. The accuracy of the readings was not disputed, but meteorology occupied quite a secondary place at Greenwich, as it was an astronomical observatory rather than a meteorological one. He thought that the Astronomer Royal should agitate for a better exposure for the meteorological instruments.

Mr. SOUTHALL remarked that the period 1823-33 seemed to be the warmest of the series, and yet the winter months were colder than the average. He had frequently noticed that the maximum temperatures during July at the Royal Observatory were much higher than at surrounding stations.

Mr. ROSTRON drew attention to the very low temperatures in the three successive Aprils of 1837, 1838, and 1839, as showing how needful it was to base averages on a long series of observations. He believed there was certainly something wrong with the Greenwich maxima observations in hot weather, for he had noticed that the differences between those recorded there and those recorded at surrounding stations seemed to grow when the temperature rose higher than 76°. Mr. Symons had said that one test of a hot summer was the number of days with a maximum above 80°. This test, applied to the Greenwich observations, say for the past summer, showed clearly the high temperatures registered there, maxima of over 80° having been recorded there on 27 days, compared with 16 days at his own station at Beddington, a few miles to the South-west.

THE PRESIDENT (Mr. Ellis) said that the printed copy of the Paper came into his hands only two days previously, and he had hardly had time to examine it. In regard to Mr. Eaton's remark that the Royal Observatory and Mr. Belville's journals were practically identical up to 1826, he considered that the identity extended further, really to the year 1830, at least the differences seemed up to that time to be in general small. Mr. Eaton, in speaking of the series of Royal Ob-

[1] *Report of the Council of the British Meteorological Society*, 1857, p. 56.

servatory observations, 1841 to 1847, states that the corrections for instrumental error were "neglected." This word conveys an entirely erroneous impression, especially considering the trouble that was really taken. The fact is that the dry bulb thermometer (on which Mr. Eaton's values entirely depend) was, in every year, compared with the adopted Observatory standard in the most systematic way, many hundred comparisons being usually made in each year, but the resulting errors being always small, no correction, as is explained, was applied. All this is fully set out in the several Introductions to the Greenwich printed volumes. To make no reference thereto, and simply say that the errors were "neglected," is evidently misleading. The maximum and minimum thermometers were similarly thoroughly compared, and their errors being generally larger were regularly applied. It should be remembered that in those days accurate standards, as we now understand them, hardly existed, and it is even now an open question whether Mr. Eaton had done well to take account of the small differences then found to exist between the dry thermometer and the presumed Observatory standard; whether indeed the one thermometer might not have been as trustworthy as the other, and whether it would not have been in any case better to have accepted the judgment of those who then discussed the results. Mr. Eaton mentions that the differences between his values and the hitherto published values are slight, and principally owing to the application of the index corrections which he had considered it better to include, thus showing that the effect on monthly means of the omission of Sunday observations is practically unimportant. In regard to the general question of Sunday observations, it should be pointed out that during the period of which he had been speaking there were no such things as photographic registers, although such were commenced at Greenwich immediately afterwards. The 1841-1847 results depend entirely on two-hourly eye observations, and, even in our day, if a similar series had to be again made, it is very doubtful whether it would be possible to get continuous work through Sunday as on week days. In Table III. Mr. Eaton gives Belville values for every hour of the day for each month on the mean of years, deduced from the few hourly values yielded by Belville's observations, which is perhaps a little more than could be legitimately deduced therefrom.

In regard to the old series of Observatory observations terminating with 1840, Mr. Eaton speaks of them as "untrustworthy," that the journals were "very imperfect," and that the self-registering thermometers were "frequently out of order," and again remarks on the "faulty condition" of the register. It should be explained that this register was one kept by the astronomical assistants of the Observatory in continuation of that commenced by Belville, not by any authority or direction, and with no stipulation to keep it complete. Such as they were, the observations were communicated to Mr. Eaton with the utmost freedom, and at his earnest request, not pretending that they in any way formed a perfect series, indeed they had never been in any way published by the Observatory authorities. He (Mr. Ellis) thought it necessary to mention this, otherwise many persons not reading with sufficient attention would undoubtedly understand the remarks as applying to observations taken under the authority of the Astronomer Royal, and deliberately published in the Greenwich volumes.

Mr. Eaton had spoken of the Glaisher stand, but it was really designed by Sir George Airy. Concerning stands, however, the readings on the Greenwich stand by day in summer are said to be too high. But if compared with readings taken in a Stevenson screen they would naturally be higher. The Royal Meteorological Society having adopted the Stevenson screen, he had always loyally advocated the use of the Stevenson screen for the Society's work—indeed he was a member of the Committee which arranged the Royal Meteorological Society pattern, but without pretending to say that the exposure in a Stevenson screen is a proper one. In some degree it appears to be artificial, contracting too much the daily range. A Stevenson screen had been put up at Greenwich, and they would soon be able to give comparison with the revolving stand. Something had been said about the confined area of the Observatory thermometer ground. But it was impossible to get more ground adjacent to the Observatory, the peninsula was quite occupied; the only possibility was to get a piece out of one of the park lawns, and if anyone could induce the people to give up a portion of one of them for Observatory purposes no doubt the

Astronomer Royal would be very glad. He might mention as regards presumed radiation effects, that in the new Greenwich thermograph the bulbs of the thermometers had been most carefully, perhaps too carefully, protected from such effects: but on five very hot days of nearly uninterrupted sunshine in the year 1886 the two principal protecting boards were alternately removed and again fixed at intervals of twenty minutes, continuing this for several hours. On extracting the readings from the photographs and arranging them according to the circumstances of boards off or on, it was found that in these two states there was no practical difference between the readings, the results being very harmonious. A similar experiment made with the circular protecting board of the revolving stand gave a like result. Another point. Although Greenwich temperatures were said to be high, the mean yearly value, taken for Greenwich from Mr. Buchan's map giving isothermals founded on twenty-four years' observations, is higher than the mean values reduced to sea level given in the last two columns of Mr. Eaton's Table VII., and so much higher than the mean values given in the preceding columns of the same table that these could in no way be harmonized with Mr. Buchan's map. Individual months had not been examined.

As respects secular increase of temperature, he did not consider this to have been proved. He might mention that the observations made by the observers who contributed to the Registrar-General's Quarterly Return, extending from the year 1849 to the present time, when divided into three groups according to latitude, 51° to 52°, 52° to 53°, and 53° to 54°, did not show increase of temperature. Individual observers became frequently changed, but the fact that each of the three groups showed practically the same thing was sufficiently significant.

This much he felt compelled to say, which done, he desired to add his testimony to the general skill and care which Mr. Eaton had displayed in a very laborious and tedious work.

Mr. EATON thanked the Fellows for the kind way in which they had received his Paper. He had only a few observations to make in reply to the discussion. With reference to the correction for instrumental errors applied to the Royal Observatory observations 1841 to 1847 (Table VI.), as the Observatory had at this time adopted a standard instrument, namely a thermometer by Newman divided to 0°·5, and ample data were given every year in the introduction to the printed observations by which all the values could be reduced to this standard, he thought it desirable to follow the indications therein laid down; and he only regretted that the "Old Series" and Belville's observations could not be treated in a similar manner. He fully agreed with the President that the hourly values in Table III. might be open to question, especially the early morning hours; but he had done the best he could with the data at command, and was inclined to think that from 8 a.m. to 10 p.m. the deduced values were very nearly if not quite accurate. At the risk of being considered captious, he must still adhere to the term "untrustworthy," as applied to the "Old Series" after 1831. He quite believed that the thermometer was read correctly, but thought that the 9 a.m. observations were sometimes taken a little too late and the 6 p.m. a little too soon. His strictures on the self-registering instruments only applied to the "Old Series" at the Royal Observatory; and self-registering thermometers in those early days were certainly far more liable to get out of order than at present. No doubt the mean yearly temperature (50°·3) at Greenwich, from Mr. Buchan's map of the isotherms of the British Isles, was higher than the values given in Table VII.; but the tables of temperature used in the preparation of the map referred to were drawn up from the simple arithmetical mean of the daily readings of the maximum and minimum thermometers, and on the authority of Mr. Buchan, in the Article "Meteorology" in the latest edition (1883) of the *Encyclopædia Britannica*,[1] the mean temperature at Greenwich by this method is 0°·4 higher than that derived from hourly observations. This would account for part of the excess noticed by the President; and the different conditions of exposure of the thermometers, used by Belville and in the Old Series of observations, from those adopted at the Royal Observatory since 1840, would, he thought, largely make up the remaining difference. One word more, although this was wandering rather beyond the scope of the Paper. He

[1] Vol. XVI. p. 119.

had stated that there had been no appreciable change in the mean annual temperature of the air at Greenwich in the period 1812 to 1855, and the President had found from the Reports of the Registrar-General from 1849 to the present date that the temperature of England as a whole had remained constant; yet, notwithstanding, he had little doubt that the temperature of Greenwich was sensibly raised by proximity to the Metropolis, of which indeed it was a suburb; and, with the present growth of population, he ventured to express an opinion that a temperature of — 5° would never in this generation be experienced near Deptford Bridge, as it had been in January 1838.

REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1887.

By the Rev. T. A. PRESTON, M.A., F.R.Met.Soc.

[Read December 21st, 1887.]

Observations have been discontinued at eight stations, while two stations have been resumed, and four additional ones have been secured in the North of England and in Scotland, through the kindness of the Editors of the *Natural History Journal*. The changes in the staff of observers have not been so great as usual.

In such investigations as these, it is very desirable to take all possible precautions to secure accuracy and uniformity. I regret, however, that objections to sending specimens are as great, if not greater, than ever. Merely glancing down the list, I could point out at least 31 species which have been mistaken by observers, sometimes from a passing similarity between the flowers, sometimes from confusing the names. Omitting instances where the observer was professedly a beginner and had to learn the species, and (for obvious reasons) not referring exclusively to this year's returns, when *Rubus cæsius* is sent for *Rosa canina*, *Polygonum convolvulus* for *Convolvulus sepium*, and *Hieracium* for *Sonchus arvensis*, besides all kinds of confusion being made between species of *Papaver*, *Malva*, *Hypericum*, *Carduus*, *Scabiosa*, *Petasites*, and so forth, it is surely not an unreasonable demand to require specimens. At a very moderate calculation, ten errors of this kind are made every year among the specimens sent; and when only one-third of the observers take the trouble that is requested, I must confess that the trustworthiness of our Record as a whole is not what it ought to be, more especially when it must be observed that some, who made errors such as I have referred to, have continued the observations, but discontinued sending specimens.

But the error is, perhaps, worse, when fully advanced specimens are selected as "first notices." Considering the very backward spring and the long period which a plant required to come to perfection, I should say that among the specimens of (*e.g.*) *Draba verna* sent in this year, some must have been in flower not less than 6 weeks, and thus, presuming the name to be correct, the date of flowering given is entirely misleading.

these remarks I shall leave this question; I cannot but feel, how-
it, when the other work of the Society has been made as perfect as
neans can do so, in this part it is far from satisfactory.
llowing is the list of stations and observers :—

Station.	*County.*	*Observer.*
on	Buckingham	J. Mathison.
	Co. Tyrone	Rev. C. L. Garnett.
ombe	Devon	E. E. Glyde.
	Lincoln	Miss F. H. Woolward.
n Weston	Dorset	Miss H. K. H. D'Aeth.
on	Bedford	J. McLaren.
one, Teesdale	York	Mrs. E. Jackson.
n	Surrey	W. F. Miller.
un	Co. Antrim	Rev. S. A. Brenan.
Maidstone	Kent	R. Cooke.
	Durham	H. J. Carpenter.
	Middlesex	A. Belt.
ey	Channel Islands	Miss M. Dauber.
len	Hertford	J. J. Willis.
	Oxford	C. U. Tripp, M.A.
	Hertford	R. T. Andrews.
k	Nottingham	Miss A. Mellish.
y	Co. Kerry	Ven. Archdeacon Wynne, M.A.
m	Kent	H. T. Stainton, F.R.S.
ield	Cheshire	John Dale.
ough	Wilts	Rev. T. N. Hart-Smith, M.A.
mpton	Northampton	H. N. Dixon.
	Oxford	F. A. Bellamy.
gton	Hants	Miss E. S. Lomer.
ry	Wilts	W. Hussey.
	Yorkshire	S. S. Burlingham. The Misses Thompson.
ld Turgiss	Hants	Rev. C. H. Griffith.
eston	Norfolk	Miss E. J. Barrow.
	York	A. B. Hall.
ston	Leicester	Rev. T. A. Preston, M.A.
on	Devon	Miss M. E. Gill.
ge Wells	Kent	G. S. Saunder.
1	Dumfries	James Shaw.
	Monmouth	C. Mostyn.
	Hertford	Lieut. R. B. Croft, R.N.
ton College	Berks	S. A. Saunders.
	Somerset	The Misses Livett.
ard Ho	Devon	H. A. Evans.
r	Co. Wicklow	The Misses Wynne.

* Send Specimens.

Botany.

The first week of *October* 1886 was exceptionally warm, and the temperature of the remainder of the month above the average. The flowering of the Jerusalem Artichoke at Peterborough (it was apparently not noticed elsewhere) is one of the best proofs of the warmth of the autumn. Vegetation was still vigorous, and wild flowers were plentiful during the month. The Ivy came into flower in the early part of the month, but (near Leicester) it never seemed to come to perfection; the uppermost flowers expanded, but all the rest on the spray remained in bud till killed by the cold. Holly and Yew berries were ripe about the middle of the month at Pennington, where also fungi were very plentiful and very large. The season was generally considered favourable for the ripening of the young wood.

Towards the end of the month, foliage had begun to turn. At Pennington the Lime was leafless, and the Beech and Chestnut in full colour, whilst some Elms and Oaks were about half turned. As a rule, however, the greater part of the foliage was still green.

November was mild and damp, and this hastened the change of leaf. A severe gale in the South-west in the middle of the month stripped the trees there, and a week later some severe frosts did the same at Salisbury. At Pennington, Scarlet Runners were gathered as late as the 18th, and at Northampton ripe Raspberries on the 20th. Wild flowers were still plentiful for the time of year, but not so much so as in 1885.

The early part of *December* was not fatal to wild flowers, though the month generally was cold and rainy. On the 26th a snow storm visited the Southern counties, and did deplorable damage to trees and shrubs. At Lewisham, "Lilacs, Laburnums, Evergreen Oaks, Birch, Fir, &c. were broken in all directions; and one double Thorn was almost annihilated, the main branches, as thick as the wrist, being broken straight through. *That one night* did more damage to our garden than all the previous 40 years." About Marlborough, it is estimated that it will take 50 years to recover from the effects. Further north, in the Midlands, snow certainly fell, but no damage appears to have been done by it.

Defoliation.

Lime, defol., Oct. 31, Pennington.

Beech, orange, Oct. 27, Detling; defol., Nov. 22, Salisbury.

Oak, half brown, Oct. 28, Detling; full tint, Nov. 18, Salisbury; defol., Nov. 17, Babbacombe.

Chestnut, defol., Nov. 10, Babbacombe; defol. nearly, Nov. 18, Salisbury.

Elm, yellow, Nov. 20, Salisbury; defol., Nov. 24, Salisbury; Nov. 3, Babbacombe.

Ivy, in flower, Oct. 1, Wicklow; Oct. 5, Hodsock; Oct. 4, Tiverton.

Number of WILD FLOWERS.

	October.		November.		December.	
	1886.	1885.	1886.	1885.	1886.	1885.
Tiverton	114	126	79	106	47	47
Pennington ...	165	—	—	—	43	—
Northampton ...	—	—	—	—	63	—

From this time the weather was most ungenial, and the year 1887 will long be remembered for its dreary winter, no spring, and intensely hot and dry summer. Vegetation suffered greatly, and as the observer at Harpenden has again furnished a very full report, I shall quote it *in extenso*, adding such other observations as may be desirable from the reports sent in from elsewhere.

January.—"The weather for the first month of the year at Harpenden opened exceedingly winterly, most of the snow which fell on December 26th still lying upon the ground; this was added to by eight small falls during the early days of January, bringing up the total depth of snow to about 12 or 14 ins. The atmosphere during the first fortnight was very cold, the night of the 2nd registering 8° only, that is 24° below freezing. The whole month gave an aggregate of 167°·7 of frost, the greater portion being registered during the first 14 days. With the third week a warmer period set in, which brought on a rapid thaw of snow and some rain. Notwithstanding, a little snow remained at the close of the month, where it had been protected from the sun's rays by the hedges.

"Much damage was done by the frost to tender out-door shrubs, and to crops of Swedish turnips exposed in the fields, where the farmers had not been fortunate enough to secure them in time.

"During the spell of fine and warmer weather in the third week of the month, the Lark frequently enlivened us with his song."

Till this milder weather set in, birds, insects, and plants were perfectly quiescent, but then there was a little change. Birds commenced their song, and Hazel and Snowdrop came into flower, but only very partially, *i.e.* at a few stations, though these are scattered all over England and Ireland: there appears to have been no regular sequence in the times of flowering; doubtless altitude of position above sea level or greater protection from surrounding objects may account for this, but it is impossible to obtain sufficient particulars. At Killarney the Sweet Violet was gathered on the 28th, but that is an exceptionally warm station. The usual winter survivals, even Chickweed and Groundsel, disappeared, and, as the observer at Croydon remarks, it was "the poorest floral January on record." As a matter of course "vegetation very backward" is the universal report.

The Honey Bee seems to have been tempted out by a few sunny days at four stations, but this cannot be considered as of any phenological importance, any more than the appearance of the solitary deluded Wasp on the 28th at Northampton.

Birds appear to have commenced singing only in the southern half of England. The Thrush was generally in song, and during the latter half of the month, the Skylark, the Chaffinch and a few other birds were heard at one or two

stations. The Rook is also reported to have commenced building at Buckhorn Weston, but, as a rule, it waited till the end of the next month. These birds (and perhaps others also) had extreme difficulty in procuring any food; not only did some die of starvation, but others were rendered so weak, that they were easily caught and killed.

February.—"An exceedingly small rainfall was experienced in this neighbourhood (Harpenden) during February, being the smallest since 1864. A little snow fell on the 2nd, and there were seventeen nights of frost, some of them being very severe. The total aggregate of frost amounted to 78°·4.

"The dryness of the weather enabled farmers to get on rapidly with Lenten corn sowing, there being some capital seed-beds obtained for Barley; but while the frosts acted as a good pulveriser of the soil, they much retarded vegetation, which was less forward than usual.

"After the disappearance of the snow of January, the reaction which took place in the plant-life of the garden extensively destroyed the Broccoli, Cabbages, and other vegetables. Many of the more tender shrubs also came to grief."

Mild weather lasted till the 5th, when cold again set in for a fortnight: then a week of mild weather, and cold returned. It was universally a very dry month, and many report that it was a bright, sunny one. Vegetation made very little progress, however, but owing to the dryness very little real damage was done, except to the green vegetables, which were universally "conspicuous by their absence." Backward as vegetation was, it was far in advance of what it was this time last year. Thus, at most stations the Hazel was earlier than last year by periods varying from 38 days to 4 days (though, on the other hand, it was 22 days later at Hertford, and 15 days later at Strathfield Turgiss). Curiously enough the Snowdrop was later by periods varying from 17 to 8 days, and earlier by 7 days at Hertford and Cardington. At Cotherstone, the gorse was 23 days earlier than last year, the Snowdrop 50 days, the Hazel 53 days, and the Chickweed as much as 66 days. Among the birds there is only one fit for comparison, that is, the Lark, which began to sing, on the average, 15 days earlier than last year.

The Hazel and Snowdrop were the only two plants in flower all over the kingdom by the end of February. The former was not seen at Strathfield Turgiss till the 27th, the same date as for Tynron, in Scotland. Vegetation hardly moved at all till the last week of the month, when the Coltsfoot and Pilewort are reported from a few localities in the southern half of England, and the Dogs' Mercury in the south-west; but the latter plant seems to have had a great struggle for existence, and to have opened its flowers with great difficulty; near Leicester not a floret was open till April. Killarney is a singularly favoured spot, Hazel (on 3rd), Pilewort (7th), Elm (8th), Daffodil (9th), Sallow (18th), Marsh Marigold (21st), and Ground Ivy (26th), all being found there this month.

Insects were naturally very scarce. The Honey Bee began working during the last week, and the Brimstone Butterfly was seen in three localities during that time.

The Song Thrush and Lark were occasionally in song, and during the last

week Rooks began their building operations, and Frogs to spawn in the South of England and in Ireland.

March.—"A more wintry and ungenial March has seldom been known. During the first eighteen days the weather was very inclement, with cloudy skies and frequent slight falls of snow, and every night during these eighteen days, without exception, the temperature of the air fell below the freezing point of water, the total aggregate degrees of frost being 118°·2.

"The mean temperature for March showed a slight deficit from the average; the closing days of the month being marked by the absence of fogs and frosts, and an improvement in the temperature with clearer skies generally, causing many plant-buds to break forth into leaf and a few spring flowers to appear.

"The vegetation in this neighbourhood at the end of March was about a month behind that of an ordinary season." (Harpenden.)

No greater confirmation of the above report could be found than the fact that almost every date recorded for March occurs within the last week. It was indeed a dreary month. "Trees as bare and Downs as brown as in the dead of winter" (Salisbury); "February promised well, but March put everything back, only 27 flowers in bloom" (Tynron); "Vegetation more backward at the end of the month than it was last year" (Northampton), are typical reports.

Towards the end of the month a change came for the better, and some few plants (Daffodils and Violets) were plentiful at some of the southern stations: even Daisies were reported as being found. But plants remained long in bud—the Cornel (*Cornus mas*) for instance remaining in coloured bud for five weeks.

The only cheering statement to be found in the reports is that "it was a good season for spring sowing."

April.—"During the greater part of April the weather was fine, dry and cold. It was only the last week that proved of a really seasonable character.

"There were a few slight falls of snow with prevailing Northerly winds. Although the weather somewhat improved after Easter, it was difficult at the end of April to believe that May had been reached, and the backwardness of the season could be ascertained from the fact, that not only were the meadows, and pastures, gardens, winter-sown Wheat and Oats remarkably behind, but the hedges and wild flowers had made but little growth. For instance, the Wood Anemone, which was observed in bloom in this district on April 5th, was 29 days later than in the average of the past seven years, that is since 1879, which was notably a very backward season. The lesser Celandine was found in bloom on April 2nd, being 22 days later than in the average of the past seven years. The common Whitlow-grass (*Draba verna*) was 15 days later in coming into flower than the average record; the Cowslip 28 days, and the Dog's Mercury (*Mercurialis perennis*) 52 days behind, this species not being observed in flower until April 10th, whereas it is frequently to be found in bloom in the middle of January. The common Daffodil of the fields was 19 days later in blooming than usual.

"The Horse Chestnut trees commenced to show leaf on April 3rd, but both leaf and flower-buds were a long time before they developed fully out.

"The *Ulmus communis* was very shy of flowering.

"Mangold seed sowing progressed favourably after rain on the 23rd." (Harpenden.)

Similar reports for April came from all quarters. At Buckhorn, on May 1st, "trees all bare, except a few leaves on the *Æsculus*; Ash not in bloom." At Salisbury, "by May 1st, Elm and Lime almost as in January. Some young leaves opened on the 18th, but since then there has been no progress." At

Northampton, "everything backward, equal to the middle of March. Elms have no tinge of green; Apples and Pears hardly any." At Guernsey, "For the first three weeks vegetation made no progress, and the Hay and Potato crops were suffering. On the 22nd rain fell and trees *burst* into leaf, but were checked again towards the end of the month. Hedges were green everywhere then, but were hardly in full leaf, and everything was 3 weeks later than last year." At Wicklow, "at the end of the month no tree was in full leaf." At Tynron, on the other hand, "flowers were behind the average, but not as late as last year."

There was a considerable amount of sunshine (Oxford), but it seemed to have done but little good on account of the drying North-east wind. Blackthorn was universally mentioned as being very poor, and specimens fully confirm this statement. It came out "very patchy," and for the first time in my experience, I saw for one day Blackthorn and Whitethorn in flower at the same time.

The early spring flowers lasted a long time in bloom. At Ealing Snowdrops were still in gardens on April 3rd, and at Thurcaston the last Aconite was seen on the 17th, and the last Crocus on the 22nd.

The Wild Thyme at Salisbury was wonderfully damaged by the cold winter. Long branches of it were quite killed, the plants breaking off near the root. Wheat suffered a good deal (at Detling) from wire-worm, and Lent corn was patchy. The Hops were shooting at the end of the month, but the shoots showed the cold weather.

Birds were very silent till May 8th (at Ealing), on which day (being bright and hot) they burst into song. At Wicklow, "the Skylark was heard in February, but was then silent till Easter Day (April 9th)."

May.—"This month gave an excess of cold, with slightly above average rainfall, but the greatest failing in the weather with regard to vegetation was the comparative lack of brilliant sunshine. The season of spring therefore passed away without showing any of that season's essential characteristics. Most of the flowering shrubs and the wild flowers of the fields which are expected to bloom in March, were only bursting into blossom at the end of May.

"The direful hail storms and the Easterly winds tore and otherwise damaged the young foliage on many of the trees, more particularly the Horse Chestnuts.

"Spring-sown corn crops were generally backward, but Wheat on good lands was looking well.

"Kitchen gardens prospered so indifferently that green vegetables were more than usually scarce and expensive to purchase. The "Fly" and the various wire-worm grubs played sad havoc among newly germinated seeds, many onion, carrot, and turnip crops being completely destroyed.

"The grub of the click beetle was found to be very abundant among potato and mangel wurzel plants."

Another cold month: the 7th, 8th, and 9th were warm and had a great effect upon vegetation, but the few trees which put forth any leaves were terribly damaged by the gale and hailstorm, as at Harpenden. Reports, as a rule, all run in the same strain. At Guernsey, "have never seen the foliage so backward by the 31st; few of the Elm trees are at all green, and some old trees in our garden have no leaves at all. Everything quite three weeks behind the average, and continued so from the cold dry weather."

The Elms were tinged on the 9th at Salisbury, and were in young leaf at Westward Ho on the 22nd; but at Northampton many were hardly showing green on the 10th, and near Leicester (as in Guernsey) some were quite bare on June 1st. The Oak was nearly in full leaf at Ealing on the 13th, but this is quite exceptional; half-leaf would be the general state, though many were still in bud. The Ash was generally a long way behind the Oak: it flowered early in the month, but foliation varied extremely in different trees. Some were nearly in full leaf on the 26th, but, as a rule, the buds had hardly begun to stir by the 31st. The Beech was in leaf by the middle of the month.

Wild flowers were not plentiful; and such as had opened had often a pinched and starved appearance. The Hawthorn just saved its name of "May" at Salisbury; "there were no flowers on the 28th, but several bushes were in flower on the 31st;" and at Lymington it was only open in warm spots. [The Poet Laureate told me that he hesitated to call the Hawthorn the "May flower," as it was so seldom in perfection in that month.] A Crab-tree at Salisbury was not in flower till the 10th; it had flowered on April 1st in 1882, and last year on May 1st. Fruit blossom was profuse, though late. "Apple and Cherry showed splendid bloom to look at, but there was a talk of maggot in the former," too sadly verified as time went on. Plums were infested with Aphis.

Swallows and Martins were rarely to be seen. There was a plague of Cockchafers at Pennington, but Butterflies and Wasps were scarce. Green Fly was very abundant.

At Usk, the dates of flowering were about five days later than last year, of insects the same, of birds one day later.

June.—"The weather for June was unusually fine and warm, there being a sudden leap from winter into summer. Winter may be said to have prevailed until the end of May, and seldom has any English summer month been better or finer than June; it has been truthfully said that 1887 has been a year without any spring.

"The violence of the climatic transition brought the meadow pasturages to rapid maturity, and enabled the haymaking to be brought quickly to a successful close. To 'make hay while the sun shines' was not a difficult process this season, and seldom has the crop been secured with so little expense in saving. The gross produce may, however, be put down at about three-fourths of an average crop.

"The sudden seasonable change in the weather further saved the harvest from being very late or very poor.

"The aspect of the growing Wheat at this period was decidedly encouraging in this district, the first Wheat ear being observed fully out of sheath on June 15th. Barley crops were looking well on good rich soils, but were miserably poor and scorched up on light and gravelly lands.

"Root crops suffered as much from the effect of the 'Fly' as from the drought; thin plants were therefore frequent, and some had to be ploughed up.

"Potato tubers were very small, the haulm of the earlier varieties being dried up too rapidly."

The great heat and want of rain were, as a rule, very detrimental. The hay was, of course, well and rapidly made (in some cases being cut one day and carried the next), though the crop was not up to the average; but vegetation suffered terribly, not only from the drought but also from insect pests, which appear to have been more than usually prevalent.

The Hay harvest began generally about the 15th, though it was as early as the 4th at Usk. In Guernsey "Strawberry bloom was profuse, but fruit none at all. Plums, Cherries, Apples, and all wall fruit were dropping from the trees. Potatoes a fair crop, but only half the proper size. The leaves were falling from the trees, as in autumn; Peas drying and withering. Only Wheat and Oats looking well." At Pennington "Roses small and bad in shape, blighted, and, on light soils, drooping, buds often not opening. Wheat thin, Barley looking bad. Shrubs and young trees looking bad. Flowers in gardens, unless watered, coming quickly into flower and seeding at once. Wild flowers mostly small, especially Daisies and Ox-eye Daisies. Lilac, Laburnum, Hawthorn, &c. in plentiful bloom till the 10th, then quickly over. The promise of Strawberries was good, but up to the end of the month only two were gathered, and they were ripe on the 18th." These two reports give very fairly a general description of the effects of the heat. Even weeds could not stand it, and, like the garden flowers, struggled into bloom and then seeded, though latterly even the Shepherd's Purse could merely ripen a few seeds, which, however, "told" when the rain did come.

The insect pests will be dealt with more fully in the Entomological Report. It may be mentioned here that *Aphis* was fearfully abundant, and the Apple trees have suffered severely from "maggot."

July.—"The weather for this month was fine, warm and dry, the rainfall for this neighbourhood being, according to the Rothamsted rain-gauge, nearly 185 tons of water per acre less than the average for July. The warmest period was during the first four days, when the maximum ranged from 83° to 86°. The heat, with the small quantity of rain since St. Swithin's Day, parched the meadows and heaths, and dried up the crops to an alarming extent on all the poorer soils, but on all the better class of soils aud wherever the land had been liberally treated in the way of manure, Wheat and Oats were able to manage on the very small supply of moisture afforded by the months of June and July.

"Barley ripened off and changed colour with wonderful rapidity, the character of the crop being generally irregular with a deficiency of straw.

"During July the county was saturated with sunshine, and whatsoever flourishes by means of sunshine and warmth did flourish. But unfortunately the whole vegetable kingdom is more or less dependent on moisture, as well as warmth and light. Those plants to which sunshine is the first essential, and which can do with little rain, promised well, while those which love plenty of moisture or which haunt marshy soils were in a bad way."

Keep for sheep and cattle was getting very scarce, and when they were turned into the fields extra fodder had to be supplied. In some cases the year's hay crop had to be used, the old hay alone being reserved for winter use.

Though some rain fell, and thus, in some degree, restored a green appearance to the meadows, the want of rain was still severely felt, as ponds and wells were running dry. Wild flowers seemed to get smaller and smaller (at Salisbury the flowers of the Canterbury Bell, *Campanula Trachelium*, were not larger than those of the Hare Bell, *C. rotundifolia*), the petals of the Shepherd's Purse barely as long as the sepals, and the upright Crowfoot, *R. acris*, in very nearly the same condition.

The Lime trees flowered profusely here and there, but, as a rule, the buds

(though very abundant) rarely expanded, and the ground under the trees was covered later on with the withered tracts and flower buds.

At Pennington "the Strawberries were almost a failure; Raspberries and Currants plentiful, but small; Peas a fair crop, but over soon; other vegetables very scarce."

The reports of the crops are much the same as that from Harpenden—short straw, and roots (especially turnips) almost a failure.

Winter Oats were cut at Lymington on the 9th, at Babbacombe on the 11th, and in Guernsey during the last week of the month. One field of Wheat was cut at Alderbury, near Salisbury, on the 30th. In all cases the crops seem to have been good.

August.—"Owing to the continued warm and dry weather the corn crops were brought rapidly to maturity, and harvesting became pretty general during the first week. The grain of most of the crops, however, appeared to dry up before it had fully developed, so that the grain generally was small and hard, and the straw short in length and of a brittle character. Barley grain was very coarsely skinned and not of a good malting quality.

"Mangolds thrive notwithstanding the drought, although the bulbs are small. All the Cabbage tribe are of a bluish colour and make little progress in growth.

"Insect life appears in its element; there has been an unusually large number of white Butterflies and Earwigs—the latter have been a perfect pest, many houses in this village being completely swarming with them.

"House flies have been more abundant than usual, which may be due to the fact that Martins, Swallows and Swifts, birds whose chief diet is insects, have been conspicuous by their absence during the recent dry period. Probably they failed to obtain the necessary mud for nest building.

"Black *Aphides* have been most plentiful, the Apple weevil is also frequent."

Harvest work progressed very rapidly. A few loads of Oats were carried at Detling on the 18th. Wheat and Barley were cut on the 2nd at Babbacombe, and all secured by the 20th; and cut on the 8th and 9th respectively at Detling, and "by the end of the month very little corn was left in the fields;" this seems late, for at Buckhorn Weston "harvest was quite finished by the middle of the month, it was "far advanced" at Salisbury by the 19th, and was over by the 20th at Pennington, and the 22nd at Hodsock.

Wild fruits, hips and haws were very plentiful; but the dry weather caused the leaves to fall prematurely; Laurels shed many of their leaves, which were quite crisp and brittle; "hedges and small trees were drooping and miserable-looking," and even large trees, near Leicester, every here and there appeared dead, only pushing out a few small leaves after the rain, to show that they still possessed some small amount of vitality.

Wasps, which had been scarce all the year, became numerous in the first or second week in different places. "Only two queens were seen, though workers were plentiful," at Cushendun. The principal entomological feature of the month was, however, the enormous amount of White Butterflies, leading some persons to imagine that there had been a migration of these insects: they will be more particularly noticed in the Entomological report.

At Strathfield Turgiss "the destruction of Moles by the iron hardness of the ground has been immense."

TABLE I.—DATE (DAY OF YEAR) OF FIRST FLOWERING.

Name of Plant.	Babbacombe.	Buckhorn Weston.	Westward Ho.	Wells.	Tiverton.	Salisbury.	Marlborough.	Strathfield T.	Wellington College.	Tunbridge Wells.	Pennington.	Henley.	Croydon.	Detling.	Ealing.	Addington.	Oxford.	Cardington.	Northampton.
ANEMONE NEMOROSA.....	..	93	..	90	97	87	86	112	135	95	102	86	96	102	..	111	..	99	98
RANUNCULUS FICARIA	72	40	54	51	61	43	35	90	..	71	63	25	92	82	98	59	..	100	81
Ranunculus acris	134	140	134	134	143	123	130	132	134	143	137	..	142	..	..	159	138	153	148
CALTHA PALUSTRIS	88	93	..	105	111	94	81	108	134	92	98	113	112	..	..	111	106	125	93
Papaver Rhœas	165	158	164	..	173	158	168	163	172	..	161	..	169	..	167	..	..	174	164
Nasturtium officinale	..	152	142	..	146	161	160	167	..	..	149	..	169	..	..	..	164	..	169
Cardamine pratensis.....	125	106	..	124	109	105	111	112	..	91	120	117	122	111	..	..	112	127	116
Sisymbrium Alliaria	..	..	..	119	111	115	125	136	143	123	125	..	121	..	128	..	116	140	120
Draba verna	74	..	59	87	62	85	93	91	69	87	..	100	85	..	..	..	..	83	37
Viola odorata	87	57	..	82	71	71	82	85	..	..	87	87	90	..	..	67	..	89	72
Polygala vulgaris	..	118	125	..	148	120	127	161	132	143	128	..	135	..	..	164	..	..	137
Lychnis Flos-cuculi	163	156	155	..	171	151	155	158	168	..	154	..	160	..	163	159	157	158	155
Stellaria Holostea	96	119	..	121	111	108	118	119	..	115	106	..	121	123	127	143	..	..	128
MALVA SYLVESTRIS	162	166	152	..	181	166	162	184	179	..	161	..	176	..	168	..	171	177	166
Hypericum tetrapterum ..	200	192	190	..	..	195	198	187	..	..	202	..	..	..	..	..	..	184	198
,, *pulchrum*	178	186	173	..	..	..	..	180	..	..	185	..	183	..	..	..	187	..	191
GERANIUM ROBERTIANUM..	109	130	128	131	136	137	146	133	..	..	132	..	142	..	..	143	129	149	142
Euonymus europæus.....	..	161	149	..	..	157	162	152	..	..	166	..	163	..	..	..	..	..	157
Acer Pseudo-platanus	..	127	..	..	130	125	138	155	150	..	130	117	128	..	127	135	143	..	137
Æsculus Hippocastaneum	134	136	139	137	136	134	142	137	..	..	137	..	133	..	136	150	135	156	146
Cytisus Laburnum	138	142	138	147	..	140	148	153	..	..	137	..	150	..	151	155	146	157	150
TRIFOLIUM REPENS	148	149	140	159	151	153	156	165	152	150	152	..	142	..	160	164	157	163	151
Lotus corniculatus	141	131	128	132	144	129	140	162	153	134	129	..	135	..	163	159	159	173	150
Vicia Cracca.....	179	165	169	..	166	174	174	157	152	..	173	..	164	..	175	178	176	179	173
,, *sepium*.....	138	112	..	131	119	119	125	130	153	..	129	..	135	141	..	..	140	..	150
Lathyrus pratensis	173	151	141	161	157	161	155	173	174	..	156	..	165	..	166	166	171	171	169
PRUNUS SPINOSA	96	111	..	116	118	98	118	115	134	120	104	113	120	127	..	114	112	93	120
Spiræa Ulmaria	178	169	176	178	..	176	174	177	..	..	202	..	183	..	..	174	176	182	182
Potentilla anserina	144	138	129	141	142	143	143	156	167	..	136	..	150	..	171	152	156	168	151
Rosa canina	167	166	164	152	168	166	167	172	168	..	173	..	169	..	169	165	166	169	169
Pyrus Aucuparia	..	151	..	..	165	..	150	142	..	..	147	..	151	..	138	155	..	..	148
Cratægus Oxyacantha	141	131	129	148	136	143	148	147	..	125	145	..	139	140	151	143	142	150	149
Epilobium hirsutum.....	193	178	184	..	..	194	190	201	..	..	198	..	189	..	..	..	200	189	204
,, *montanum*	..	..	164	167	168	175	166	..	183	..	166	..	170	..	174	..	..	175	169
Angelica sylvestris	..	216	..	..	..	207	211	212	..	..	224	..	..	..	..	..	..	..	204
Daucus Carota	..	168	180	..	214	174	174	153	..	..	177	..	183	..	..	..	189	..	187
HEDERA HELIX.....	270	..	..	..	..	256	..	..	..	..	..	..	268	..	..	..	..	..	250
Cornus sanguinea... ...	..	167	..	..	..	167	171	182	..	..	174	..	177	..	175	..	176	..	177
Viscum album	134	136	137	137	136	136	165	143	..	..	134	..	136	143	137	138	125	..	136

Name of Plant.	Usk.	Harpenden.	Hertford.	Ware.	Thurcaston.	Belton.	Tadcaster.	Hodsock.	Macclesfield.	Thirsk.	Settle.	Teesdale.	Durham.	Tynron.	Arboe.	Cushendun.	Killarney.	Wicklow.	Guernsey.
ANEMONE NEMOROSA	90	95	95	104	90	..	102	100	117	..	101	87	99	103	99	94	..	88	111
RANUNCULUS FICARIA	56	92	72	..	65	..	58	70	95	62	88	59	..	99	47	53	38	44	..
Ranunculus acris	127	134	109	..	141	137	..	154	160	..	145	151	..	140	109	..	141	142	119
CALTHA PALUSTRIS	90	122	110	125	109	..	113	109	134	..	101	112	..	124	110	99	56	120	115
Papaver Rhœas	161	159	150	..	186	..	164	172	..	..	..	..	..	..	187	..	..	164	164
Nasturtium officinale	..	..	..	..	173	..	148	176	..	..	144	162	..	..	154	..	161	156	145
Cardamine pratensis	102	126	124	..	114	..	..	115	..	..	..	..	..	..	109	105	108	127	120
Sisymbrium Alliaria	..	122	115	..	122	135	113	128	..	..	..	..	..	..	..	..	120	124	120
Draba verna	..	92	100	..	106	..	..	..	..	..	103	82	..	124	..	..	..	41	..
Viola odorata	79	71	92	..	82	..	52	70	..	75	..	..	..	79	..	..	28	67	..
Polygala vulgaris	165	169	..	..	163	..	..	..	..	..	138	..	..	140	148	126	134	126	106
Lychnis Flos-cuculi	159	160	..	..	161	..	154	155	173	..	..	171	..	159	165	..	163	158	133
Stellaria Holostea	112	113	126	119	122	..	117	126	138	..	136	126	..	135	108	115	102	106	..
MALVA SYLVESTRIS	173	192	..	165	176	..	164	182	184	..	..	172	..	..	170	..	..	157	159
Hypericum tetrapterum	178	197	..	..	..	..	..	201	..	..	188	..	..	196	181	..	180	197	194
,, *pulchrum*	181	198	..	..	..	..	..	..	187	..	188	..	..	191	180	..	177	..	177
GERANIUM ROBERTIANUM	132	141	121	..	128	144	133	149	..	..	138	157	..	154	133	132	100	114	111
Euonymus europœus	161	..	166	..	..	..	..	166	..	..	..	..	..	..	..	..	144	..	..
Acer Pseudo-platanus	129	133	135	..	140	135	..	127	..	..	141	159	..	156	122	146	115	..	130
Æsculus Hippocastaneum	137	143	135	140	145	143	147	138	156	..	150	159	..	156	138	..	128	134	133
Cytisus Laburnum	145	153	143	..	156	..	157	148	162	..	..	172	..	156	138	141	134	136	136
TRIFOLIUM REPENS	158	160	158	157	155	..	..	160	163	..	..	168	..	158	144	142	143	114	137
Lotus corniculatus	128	164	155	..	144	..	138	158	155	..	138	169	159	140	144	122	126	114	127
Vicia Cracca	173	180	143	..	177	..	177	186	177	..	..	..	..	158	173	..	169	172	180
,, *sepium*	132	137	135	135	141	..	116	158	150	..	133	..	..	..	170	122	109	114	133
Lathyrus pratensis	162	165	140	..	174	..	..	178	173	..	..	..	..	168	154	165	163	159	184
PRUNUS SPINOSA	107	112	..	118	111	..	123	111	..	..	118	130	..	123	106	99	..	101	94
Spiræa Ulmaria	173	188	177	..	183	..	..	177	185	..	..	180	..	186	164	176	172	173	..
Potentilla anserina	133	155	154	137	147	..	158	163	..	..	146	166	159	161	138	127	134	123	141
Rosa canina	167	162	166	164	170	..	171	170	179	..	..	172	172	166	158	158	153	164	181
Pyrus Aucuparia	147	152	165	..	147	148	..	156	156	..	..	188	..	154	144	..	142	155	139
Cratægus Oxyacantha	132	153	142	..	147	..	148	154	160	..	146	165	..	156	143	142	129	138	140
Epilobium hirsutum	..	196	168	..	200	..	202	192	..	..	207	..	..	..	173	..	183	188	197
,, *montanum*	169	181	163	..	167	..	..	..	..	..	..	..	..	161	164	172	159	160	171
Angelica sylvestris	..	..	179	125	..	..	..	213	..	..	197	..	..	201	192	..	..	..	..
Daucus Carota	..	..	..	..	..	..	..	..	..	..	..	..	..	..	180	159	..	170	145
HEDERA HELIX	..	..	..	..	..	..	..	266	..	..	..	..	..	..	..	..	244	261	266
Cornus sanguinea	155	177	..	..	182	..	..	160	..	..	..	..	..	..	..	..	141	..	..
Syringa vulgaris	138	137	130	..	148	143	146	143	152	..	151	152	..	..	132	129	130	131	133
Galium Aparine	149	153	144	151	155	..	..	158	180	..	..	180	..	..	171	..	153	162	145

TABLE I.—Date (Day of Year) of First Flowering.—*Continued.*

Name of Plant.	Babbacombe.	Buckhorn Weston.	Westward Ho.	Wells.	Tiverton.	Salisbury.	Marlborough.	Strathfield T.	Wellington College.	Tunbridge Wells.	Pennington.	Henley.	Croydon.	Detling.	Ealing.	Addington.	Oxford.	Cardington.	Northampton.
Galium verum	177	183	177	180	..	174	179	202	..	..	185	..	191	141	..	178	181	176	182
Dipsacus sylvestris	..	196	..	..	..	206	..	212	..	..	202	..	205	..	..	..	200	..	205
Scabiosa succisa	211	220	190	..	213	175	..	203	202	..	202	..	..	..	..	..	..	..	231
Petasites vulgaris	..	12	..	89	94	88	37	100	..	112	..	119	..	..	..	..	84	..	93
Tussilago Farfara	87	60	59	..	85	82	36	87	..	61	82	94	56	102	99	80	90	86	56
Achillea Millefolium ..	176	169	173	178	168	164	170	188	163	..	173	..	182	..	182	..	186	181	179
Chrysanthemum Leucanth.	150	134	149	152	159	143	144	151	172	148	149	..	150	..	160	..	151	135	155
Artemisia vulgaris	..	..	..	..	..	207	218	214	..	..	208	..	..	..	..	..	..	183	229
Senecio Jacobæa	178	156	180	..	181	..	174	158	186	..	182	..	177	..	..	..	..	170	189
Centaurea nigra.....	192	187	..	176	..	175	172	172	..	..	182	..	176	..	174	..	..	190	173
Carduus lanceolatus	180	..	177	..	..	194	190	..	..	..	..	..	194	..	191	..	185	183	189
„ *arvensis*	184	188	178	..	..	190	185	172	..	..	202	..	184	..	189	..	..	..	187
Sonchus arvensis	..	199	191	..	213	217	201	209	..	..	203	..	196	..	..	..	..	..	..
Hieracium Pilosella	148	151	158	155	146	136	148	152	..	..	136	..	151	..	162	159	155	..	155
Campanula rotundifolia	..	..	..	..	..	197	181	197	202	..	173	..	198	..	..	..	..	..	191
Ligustrum vulgare	173	152	..	..	181	165	170	184	..	..	170	..	177	..	..	..	171	..	182
Convolvulus sepium	200	181	167	..	..	197	184	178	188	..	202	..	189	..	189	..	195	..	192
Symphytum officinale	180	130	163	130	..	131	129	163	..	150	145	..	160	..	..	..	129	..	134
Pedicularis sylvatica	..	147	146	..	132	122	135	129	157	128	128	..	149	..	..	..	..	..	137
Veronica Chamædrys	96	114	121	131	118	108	120	131	134	118	113	..	127	..	91	130	128	142	135
Mentha aquatica	216	216	..	..	..	216	218	221	..	..	208	..	..	..	..	..	..	..	217
Thymus Serpyllum	168	..	173	173	..	161	163	174	199	..	165	..	191	..	..	..	160	..	165
Prunella vulgaris.....	168	167	172	..	171	175	169	173	..	..	170	..	177	..	..	164	166	..	171
Nepeta Glechoma	74	64	65	98	84	89	85	123	134	92	91	98	114	109	99	88	99	128	97
Galeopsis Tetrahit	..	204	197	..	..	190	199	167	..	..	224	..	..	..	..	..	94	..	198
Stachys sylvatica	..	169	169	..	168	167	167	182	163	..	167	..	177	..	169	..	171	..	173
Ajuga reptans	125	111	120	129	136	125	127	131	152	120	120	..	127	..	142	125	138	..	136
Primula veris.....	93	88	..	98	..	99	111	111	132	106	112	104	117	..	..	99	109	126	113
Plantago lanceolata	113	114	127	..	118	108	120	123	..	120	118	..	125	..	135	119	115	134	129
Mercurialis perennis.....	87	53	59	52	61	59	63	98	75	60	76	53	78	92	..	..	90	..	92
Ulmus montana	75	..	..	..	..	85	89	116	..	..	87	..	..	89	..	101	..	82	86
Salix caprea	69	89	61	82	..	87	89	122	..	74	76	93	92	88	94	..	..	..	92
Fagus sylvatica	..	126	..	..	148	133	137	148	..	..	142	..	..	..	121	..	..	..	138
Corylus Avellana....	38	40	30	35	31	22	36	58	..	53	35	33	30	38	..	..	33	45	37
Orchis maculata	173	..	..	164	..	164	170	128	169	122	156	..	169	..	..	..	..	..	164
Iris Pseud-acorus.....	161	166	159	..	159	158	162	183	..	..	152	..	169	..	168	..	167	..	169
Narcissus Pseudo-narcissus	..	90	75	..	..	..	71	92	87	93	94	92	..	..	..	94	..	101	92
Galanthus nivalis	..	32	..	..	28	22	27	28	..	..	..	29	23	56	32	..	..	37	38

Name of Plant.	Oak.	Harpenden.	Hertford.	Ware.	Thurcaston.	Belton.	Tacolneston.	Hodsock.	Macclesfield	Thirsk.	Settle.	Teesdale.	Durham.	Tynron.	Arboe.	Cushendun.	Killarney.	Wicklow.	Guernsey.
Galium verum	..	181	170	..	181	..	..	186	..	..	..	..	..	166	180	..	180	192	166
Dipsacus sylvestris	..	..	..	..	201	..	..	207	..	..	..	..	..	..	..	206	..	..	196
Scabiosa succisa	..	..	..	..	197	..	..	..	205	..	211	207	..	191	204	..	162	..	..
Petasites vulgaris.....	88	..	91	..	..	..	..	100	..	..	89	113	108	99	95	..	..	..	..
TUSSILAGO FARFARA ...	56	83	47	92	85	..	..	54	..	62	57	97	76	86	59	56	77	67	..
ACHILLEA MILLEFOLIUM .	174	174	176	..	175	..	175	177	187	..	..	191	..	196	176	..	165	168	166
Chrysanthemum Leucanth.	150	152	154	..	162	..	157	162	173	..	..	169	..	166	154	148	149	138	117
Artemisia vulgaris	..	..	..	..	..	..	..	208	..	..	..	..	..	212	..	..	201	..	204
Senecio Jacobæa	..	196	181	..	..	..	..	194	181	..	185	..	..	196	170	176	171	180	164
CENTAURIA NIGRA.....	173	181	166	..	178	..	171	177	180	..	..	199	..	199	178	..	183	178	175
Carduus lanceolatus.....	173	186	177	..	192	..	..	201	183	..	207	..	..	193	175	158	180	..	182
„ *arvensis*	..	187	177	..	191	..	..	186	189	..	202	..	..	201	164	..	175	..	184
Sonchus arvensis	..	192	170	..	..	..	..	203	197	..	189	..	..	..	186	..	183	..	192
Hieracium Pilosella	151	167	152	..	..	..	154	160	163	..	..	171	..	161	154	147	135	145	137
CAMPANULA ROTUNDIFOLIA	..	177	177	..	199	..	..	192	180	..	..	191	..	196	..	..	..	..	..
Ligustrum vulgare.....	174	176	180	..	180	..	..	186	183	..	194	198	..	..	170	..	162	169	169
CONVOLVULUS SEPIUM	..	203	..	..	221	..	203	189	190	..	..	..	..	..	183	..	184	182	177
Symphytum officinale	131	..	158	..	144	..	..	..	189	..	..	..	..	150	165	..	159	157	154
Pedicularis sylvatica	137	..	157	..	134	..	..	..	..	..	146	158	..	..	122	129	119	117	107
Veronica Chamædrys	125	130	131	..	138	..	122	137	150	..	138	130	..	135	102	108	116	129	109
Mentha aquatica	..	..	..	..	227	..	211	218	..	..	..	..	..	..	196	..	197	192	204
Thymus Serpyllum	..	189	160	..	..	..	..	..	197	..	..	180	..	169	..	..	181	..	164
Prunella vulgaris	171	175	181	..	181	..	..	..	156	..	..	..	..	..	170	166	160	170	141
Nepeta Glechoma	87	96	91	106	107	..	78	108	134	..	108	106	108	132	103	95	57	107	105
Galeopsis Tetrahit	..	..	181	..	..	..	..	..	..	..	..	..	..	196	..	..	..	..	..
Stachys sylvatica	169	171	176	175	175	..	..	..	183	..	..	..	..	169	170	..	..	166	159
Ajuga reptans	132	130	..	145	127	..	130	131	..	..	133	..	166	140	121	136	114	132	123
PRIMULA VERIS	112	107	107	106	107	..	102	110	141	..	93	130	113	..	..	..	..	98	..
Plantago lanceolata.....	128	123	..	128	122	..	..	128	..	..	126	..	..	135	..	119	108	100	105
Mercurialis perennis	62	100	95	159	106	..	87	85	..	51	63	85	..	89	..	..	..	..	..
Ulmus montana.....	70	89	71	..	89	..	..	80	..	..	95	..	..	..	..	101	39	..	..
Salix caprea	68	90	86	..	89	..	73	75	..	77	88	106	..	..	67	75	49	45	93
Fagus sylvatica	134	147	..	..	134	139	..	139	..	..	..	..	..	147	..	114	..	..	..
Corylus Avellana	29	44	25	..	..	31	36	29	..	30	28	47	..	58	64	50	34	24	..
Orchis maculata	152	171	174	..	160	..	..	..	..	..	..	164	..	156	..	147	150	163	145
Iris Pseud-acorus	159	169	172	159	197	..	..	161	..	..	..	..	..	..	157	148	150	160	137
Narcissus Pseudo-narcissus	81	94	90	..	94	..	..	93	..	..	..	..	..	..	62	61	40	..	..
Galanthus nivalis	16	35	30	43	..	..	..	31	..	29	51	43	..	..	22	26	20	22	..
SCILLA NUTANS	125	128	127	..	122	..	131	132	145	..	113	113	..	..	112	126	77	110	101

September.—The timely rain at the beginning of the month arrested the fall of the leaf and much improved vegetation. The small amount of growth which most of the trees and shrubs were able to make took place now. "The second flowering of Roses was a failure, and the plants made no new wood" (Pennington). Quite towards the end of the month the autumn tints began to appear. At Salisbury three Elms had large patches on the 28th, and the Limes began to get sere: and in Guernsey the Beech, Chestnut, Sycamore, and Lime began to shed their leaves very fast during the last ten days of the month.

At Pennington "the Jerusalem Artichoke flowered splendidly; but the tubers ripened off so rapidly that there were not many fit for the table." I am surprised that no reports have reached me of its flowering elsewhere.

Mushrooms were in extraordinary quantities in Wicklow, and the hedges generally were a mass of hips and haws; and Blackberries were never so plentiful before in Guernsey. Apples fell very fast, most of them injured by grubs, but the best were blown off by the wind. Potatoes were a better crop than was expected, though often very small. The effects of the swarms of White Butterflies last month began to be painfully evident—Cabbages of all kinds were reduced to skeletons. In Suffolk "there seemed to be quite a dearth of insects in the day-time, except Wasps, which were quite a plague; I saw quarts and quarts of them"—(F. N. Pierce in *Young Naturalist*).

At Pennington a Corncrake was killed on the 1st, it had not been seen or heard since April 24th.

The past season must therefore be considered a most exceptional one. For flowers it has been nothing less than disastrous; fruit generally has been a failure, though there are exceptions—those kinds which promised well turned out very small or spoilt by insects; vegetables were universally poor; roots destroyed by insect or drought, and green crops soon passing off. But with all this, there are subjects for congratulation. The Wheat crop improved a good deal latterly, and the result was better than was expected. Barley on light lands was poor, but that which was sown early was satisfactory. The meadow Hay was not up to an average crop, but Clover and seed Hay were much more nearly so. In Kent the fruit crops turned out lighter than usual, but prices have ruled higher, and the result will be a better profit than last year. The drought did away with anticipated "big profits," but "in the abstract moderate yields always bring better prices than glut does," and as other countries do not appear to have fared better than we have, "there is some comfort for the British farmer in the reflection that there is a likelihood of his produce improving ere long greatly in value."

Entomology.

The very short list of insects to be observed, and the fact that in that short list are insects of so many different orders, render the notices very

scanty, and (it must be confessed) unsatisfactory. Having had no hand in drawing up the list, I am unable to find out the special object of selecting those species—those which are put down for observing early in the year are too much influenced by a single bright day to render any notices of their appearance then of any importance. Thus, taking the species in the order of the average dates of their appearance, we have, first, the Honey Bee. Bright days in January will bring them out, even when snow is on the ground; there are no flowers for them to work at, consequently they merely get chilled and perish in the snow. Of the 20 notices sent in, 5 are in January, 7 in February, 6 in March, and 2 in April. Flowers hardly began to open till quite the end of February, and then the Crocus appeared. The average date for the appearance of this insect is February 27th, and this is the very earliest time that they could have worked, though the cold weather in March must have stopped them again. This date is, however, interesting as bringing out the fact that February plants were earlier than last year. If the Honey Bee is to be observed at all, a far more important phenological date would be that of "first swarm," and I trust observers will add this date in future.

The next species in order is the Small White Butterfly. No notice is sent in for this species from any place in the North of England. It was nearly a fortnight earlier this year than last, and the dates are singularly near one another. The first notice is from Marlborough, March 26th, the next at Ealing, the 28th, and within a week it had appeared generally. It was not noticed at Ware till April 28th, or at Addington till May 1st; it almost seems as if it had been overlooked at these places. Later on in the year, in August, this species appeared in many parts of England in enormous quantities. (At Pennington, 620 Butterflies, nearly all *P. Rapæ* were caught in one week.) So numerous were they, and so worn when first observed, that many persons thought there must have been a migration of them from the Continent, but this need not have been the case, for, as was pointed out by Mr. Weir (*Ent. M. Mag.* Vol. XXIV. p. 13), the circumstances favourable for the perfection of these insects may have been unusually numerous this year, and a single additional favouring circumstance, or the removal of an unfavouring one, may make a vast difference in the number of insects produced. Any one who has attempted to rear insects must have been struck with the number of caterpillars which are destroyed by the various species of Ichneumon Fly. Mr. G. McMurtrie (in the *Entomologist*, Vol. XX. p. 227) experimented with these flies; and found that "if exposed to very unusual heat from the sun, they speedily die. If this be the case in nature (which I see no reason to doubt), and as we have had an unusually hot summer, it is probable that large numbers would die off, and consequently a larger percentage of larvæ would escape unstung, and the Butterflies emerge from their chrysalids." This certainly may be one reason why this swarm, unequalled for nearly 40 years, has visited us this year.

The Bloody-nosed Beetle is a very unsatisfactory insect for observation, as the larva is frequently mistaken for the perfect insect. The two are not very unlike (especially to non-entomological eyes), and this may account for the

difference in the dates recorded. Of the six dates sent in, the earliest is February 28rd, and the latest May 7th. No phenological inferences can be drawn from this. The Wasp, next in order, is again an insect which hybernates, and is attracted from its winter quarters by a bright day, but only to perish for its temerity, though it seems to be far superior in intelligence to the Bee in this respect. It was observed at 1 station in January, 2 in February, 1 in March, 7 in April, and 8 in May. The average date is April 16th. The above records help to show how ungenial were the first three months of the year.

The Large White Butterfly is, I fear, often confounded with the Small White. At Harpenden alone was it observed before the Small White, though in Guernsey it was only one day later. At Hodsock it was recorded as being seen on April 11th, but no date is given for the Small White. Allowing these dates to stand, its average date of appearance is 25 days later than that of the Small White. At Westward Ho it was no less than 58 days later, and it appears to be exceptionally late there. I should be very glad to receive the specimens observed. In August, when the swarms of *P. Rapæ* were noticed, in many places the Large White was equally abundant, though there seem to have been exceptions.

The Orange-tip Butterfly is certainly a well-marked species, and a very attractive one; though the female is not easy to distinguish, on the wing, from the Small White. I am surprised, therefore, to find such great variations in the dates of first appearance of this insect. It is reported as having been seen at Harpenden on March 31st, but not till June 12th at Ealing. The average date is May 14th. It has been abundant in some localities, but, judging from the reports, not many.

The Cockchafer was about 6 days earlier this year than last. It appeared on April 11th at Buckhorn Weston, but not till June 6th at Harpenden, an interval of 56 days. Large as this is, there is no special date at which the insect generally appeared: the average date was May 16th.

The Meadow Brown Butterfly is another insect which, I cannot help thinking, is not perfectly understood. Every year there are some very great extremes, and this year is no exception. It was noticed at Cushendun on April 5th, and at Cardington on April 12th; but not till June 30th at Babbacombe, and July 4th at Thurcaston. The average of all the dates is June 2nd, but, omitting the very early ones, June 19th.

The Glow-worm was singularly early at Tynron (May 14th), and the observer remarks that it is the first time (in 24 years) that he had noticed it so early, as it is not generally seen till after Midsummer Day; in the present case the light was decidedly less brilliant than usual. The latest notice was at Strathfield Turgiss, where it was not seen till July 15th, 62 days after its appearance at Tynron.

The Fern Chafer is still more extraordinary. It was seen at Ealing on April 5th, but not till July 7th at Cardington and Northampton. Omitting the former date, the three others give an average of July 1st, which would be about the usual date for this species.

TABLE II.—INSECTS AND FROG SPAWN.

Stations.	*Melolontha vulgaris.*	*Rhizotrogus solstitialis.*	*Timarcha laevigata.*	*Lampyris noctiluca.*	*Apis mellifica.*	*Vespa vulgaris.*	*Pieris Brassicæ.*	*Pieris Rapæ.*	*Anthocharis Cardamines.*	*Epinephile Janira.*	*Bibio Marci.*	*Goriopteryx. Rhamni.*	Frog Spawn.	Tadpoles.
Babbacombe ..	..	..	..	..	..	..	..	93	..	180	..	..	..	..
Buckhorn W.	101	..	54	..	27	101	118	107	118	131	..	87	64	..
Westward Ho	145	..	81	172	..	93	151	93	125	167	..	..	..	..
Salisbury	..	..	..	..	53	123	..	101	129	..	..	..	52	96
Marlborough..	127	170	127	..	81	..	124	85	135	168	117	..	50	..
Strathfield T.	151	..	..	196	70	114	121	109	151	165	..	..	87	..
Pennington ..	150	..	156[1]	193	57	149	..	97	149	175	..	56	52	..
Henley	..	..	92	..	..	55	..	96?	..	..	..	58	60	96
Detling	..	..	..	..	57	129	..	94	151	..	..	93	..	..
Ealing	..	95	..	..	87	..	..	87	163	177	..	..	91	..
Addington	..	..	..	..	..	127	150	121	142	171	..	88	83	..
Oxford	121	..	..	..	108	..	..	108	..	..	..	..	..	..
Cardington ..	..	188	..	..	52	135	..	100	..	102	..	..	..	..
Northampton	..	188	113	..	81	28	..	108	155	..	..	..	..	112
Usk	138	..	..	142	56	98	135	102	102	172	134	87	..	157
Harpenden ..	157	..	103	173	36	108	101	107	90	128	162	..	85	..
Hertford	155	..	..	..	19	125	..	94	135	..	..	..	76	..
Ware	..	..	..	..	20	..	..	118	..	..	..	..	82	..
Thurcaston ..	..	..	..	..	102	56[2]	..	109	..	185	..	..	..	..
Belton	..	..	..	..	27	..	..	..	..	..	..	..	..	..
Tacolneston ..	..	..	..	..	28	..	..	..	150	..	..	59	98	..
Hodsock	..	..	..	..	50	130[3]	101	..	152	..	..	..	69	107
Macclesfield ..	..	..	..	..	..	143	..	..	..	..	..	..	..	..
Tynron	..	..	..	134	..	..	..	..	..	..	..	..	74?	..
Durham	..	..	..	..	..	..	167	106	..	..	..	..	..	..
Arboe	105	..	..	..	..	120	147	103	104	165	..	..	57	119
Cushendun ..	..	..	..	..	[4]	95	..	97	..	95	..	..	47	..
Killarney	143	..	..	..	84	88	142	102	..	..	..	..	..	..
Wicklow	..	..	..	..	62	..	134	98	128	145	..	..	53	..
Guernsey	..	..	..	..	..	..	94	93	..	130	127	..	..	..
Average	136	182	103	168	58	106	126	101	134	153	135	75	69	..

[1] Larva. [2] Wasp 56 and 158. [3] Nest 168. [4] Swarmed 151.

St. Mark's Fly was seen at Marlborough on April 17th, and at Harpenden on June 11th.

One other species, the Brimstone Butterfly, is worth noting. It was seen at Pennington on February 25th, and at Detling on April 3rd, the average date being March 16th. This species hybernates, and is, of course, liable to be lured out by a fine day, but it is certainly the most satisfactory of all these early insects for observation. Of the 7 dates recorded, 3 are in the latter part of February and the other 4 in the week preceding April 3rd, just the times when the weather became temporarily milder.

Comparing the dates of the species seen at the same places during the past 3 years, and placing them according to the average time of appearance, we get

	1885.	1886.	1887.	1887 differs from 1886.
Brimstone Butterfly	100	82	71	−11
Bloody-nosed Beetle	76	76	78	+ 2

	1885.	1886.	1887.	1887 differs from 1886.
Small White Butterfly	107	116	103	−13
Large White Butterfly	120	122	122	0
Orange-tip Butterfly	135	129	131	+ 2
Cockchafer	138	143	137	− 6
Meadow Brown Butterfly	154	151	146	− 5
Glowworm	147	172	184	+12

With respect to insect pests and insects generally, there seems to have been very little to notice in the first 3 months of the year.

In April Wire-worm was noticed at the corn (Detling), and from this time complaints came thick and fast. In May the "Green Fly" appeared in great quantities, Wire-worm at work, and Apple blossom much attacked by larvæ. In some instances the stalks of the bloom were injured close to the branch of the tree, and consequently the whole perished. Some trees wore a miserable appearance from the masses of bloom thus killed. At Pennington there was a plague of Cockchafers.

In June, at Detling "there have been a few fly more or less in the Mid Kent Hop districts, but the hot sun seems to have prevented their increase to a great extent. The accounts from the Weald of Kent and Sussex are more serious. Apples, which gave a splendid bloom, have been fearfully injured by maggot, and Nuts have suffered severely from a leaf caterpillar." At Pennington "Pear-tree slug has reappeared for the third season. Currants and Gooseberries have the Palmer worm (probably the saw-fly; the larva of the Gooseberry Moth appears not to have been very numerous as a rule); Roses have the *Aphis* and several caterpillars; Plums, &c., smothered with Green and Black Fly." The Mangold had to be ploughed up and re-sown.

At Hertford "Insects (except wasps and hornets) of all kinds very abundant. Many Oaks, some Elms, a few Beech, many Willows and Sallows, have their foliage entirely destroyed by larvæ. Oak-apples are plentiful. Very much honey-dew."

At Usk the *Aphides* were so numerous that under the trees "the dripping of Honey-dew gave the ground the appearance as if rain had fallen."

In July, at Pennington, "Pear-tree slug numerous, but considerably lessened by hand-picking. Small fruit-trees were very blighted, and Turnip Fly everywhere."

At Ealing and elsewhere "insect life has been very abundant during the month."

In August Wasps became numerous, and the White Butterflies in swarms —these have been noticed elsewhere. But Butterflies and Moths seem to have been very abundant, judging from the accounts given in the entomological publications.

In September, at Pennington, "Wasps very abundant. Bees and honey plentiful—*Pieris Brassicæ* and *Rapæ*, *Rhamni* and Common Blues plentiful, especially *P. Rapæ*. *A. Cardamines* very scarce. *Atalanta*, Painted Ladies, and Green-veined Whites, were to be seen."

This, I think, must be considered as one of the entomological features of the year—viz. the very great prevalence of some of our common butterflies, and the almost total absence of others.

Frog spawn has been generally observed, but the dates recorded vary enormously. It was noticed first at Cushendun on February 16th, and in the rest of Ireland before the end of February. In the South-Western and Southern counties of England in February, or very early in March; but at Strathfield Turgiss and Ealing not till the end of March and beginning of April. In the Midland Counties towards the end of March, and in Norfolk not till April 8th. The average date is March 10th, one day earlier than last year; but if only those dates are taken where it has been observed for three years, the average dates are March 15th, 1885, March 22nd, 1886, and March 8th, 1887, thus making it 14 days earlier than last year, and 7 days earlier than in 1885.

Ornithology.

Song.—The Song-Thrush did not begin to sing till about the last week in January, when it was heard very generally over England; and was a fortnight earlier than last year. The Skylark was 11 days later than the Thrush, and began to sing 15 days earlier than last year; thus bearing out the fact that February was perhaps the mildest month of the three spring ones. But though the above dates are only the averages of the dates recorded, the differences between the dates themselves are extraordinary, and can furnish no reliable data. At Buckhorn Weston the Lark began singing 69 days after the Thrush, at Salisbury and Wellington College 31 days, whilst at Pennington it was 6 days earlier, at Usk 27 days later, and at Harpenden 12 days earlier.

The Chaffinch, again, was heard at Cushendun on January 20th, but at Cardington not till May 5th: as only 8 notices are recorded, giving an interval of 105 days between the earliest and latest, no results can be deduced.

The Chiff-chaff was heard as early as March 13th, but at Strathfield Turgiss not till May 13th. It seems to have appeared generally in April.

The Willow-wren began to sing during the latter half of April, and during this time the Cuckoo generally arrived. The latest date recorded is May 7th, at Ealing, a week later than at Macclesfield and Tynron. Its average date is one day later than last year, but then it was heard unusually early at Cushendun (March 25th), and this very early date made the average date earlier, so that it may be considered that the Cuckoo was really earlier this year than last.

The Nightingale was also earlier this year than last, even reckoning the dates for Marlborough (May 3rd), Buckhorn Weston (May 7th), and Wellington College (May 12th). At Marlborough it is rarely heard, and it is quite possible that the Easter Holidays there and at Wellington College may have affected the "first notice." At Buckhorn Weston it is the first notice

TABLE III.—Birds.

Stations.	Song.								Migration.							
	Song Thrush.	Nightingale.	Willow Wren.	Chiff-chaff.	Skylark.	Chaffinch.	Cuckoo.	Turtle Dove.	Flycatcher.	Wheatear.	Swallow.	House Martin.	Sand Martin.	Swift.	Goatsucker.	Corncrake.
Babbacombe ..	..	..	..	..	..	..	108	..	..	..	124	..	..	141	..	..
Buckhorn W.	15[1]	127	..	133	84	92	105	..	148	..	110	111	..	121	..	128
Westward Ho	29	..	115	98	..	..	118	..	..	87	102	120	..	121	..	129
Wells	..	..	..	..	..	..	115	..	..	..	..	..	..	..	..	..
Tiverton	..	..	..	..	..	..	118	..	..	..	..	..	..	..	..	..
Salisbury	24	109	..	..	55	..	102	..	165	..	110	118	96	124	..	129
Marlborough..	30	123	127	72	27	..	114	121	140	..	97	82	120	120	134	123
Strathfield T.	..	115	114	139	36	85	107	123	143	128	112	122	..	133	..	130
Wellington Col.	28	132	..	..	59	29	114	128	128	..	102	..	..	132	..	..
Tunbridge W.	..	..	..	..	53	..	102	..	..	..	120	..	..	..	..	..
Pennington ..	37	104	..	102	31	..	111	..	..	..	109	..	..	122	128	114
Henley	..	..	..	..	..	..	112	..	..	..	..	..	..	..	..	..
Detling	..	109	..	..	21	..	102	..	..	..	..	116	..	140	127	..
Ealing	21	116	..	91?	28	..	127	..	..	..	..	106	..	133	..	..
Lewisham	..	..	..	..	..	24	..	..	..	..	..	..	..	..	..	..
Addington....	27	116	..	..	..	..	112	123	..	..	103	..	149	139	..	..
Oxford	..	..	..	..	25	..	114	..	..	..	105	..	104	124	..	127
Cardington ..	29	117	121	..	..	125	114	..	..	..	112	..	..	..	..	146
Northampton	28	..	..	..	..	..	114	..	135	..	117	125	129	137	..	..
Harpenden ..	33	111	..	..	21	..	106	..	..	..	112	122	..	123	..	106
Usk	26	..	88	84	53	31	117	118	105	..	99	109	99	142	..	124
Hertford	22	112	..	..	26	..	115	..	..	..	108	..	..	..	..	..
Ware	..	113	..	85	20	..	114	..	..	..	113	134	..	133	..	136
Thurcaston ..	..	..	..	..	..	..	119	..	..	..	..	..	..	..	..	128
Belton	25	..	..	..	27	..	..	..	..	..	..	..	..	137	..	127
Tacolneston ..	30	117	107	..	24	..	118	138	..	..	113	125	..	..	..	..
Hodsock.....	38	119	..	109	37	104	119	..	140	..	117	..	119	135	172	120
Macclesfield ..	..	..	..	..	..	..	120	..	..	..	124	..	..	151	..	145
Tynron	..	..	..	..	..	..	120	..	..	..	..	121	..	..	..	..
Teesdale	..	..	..	..	..	..	121	..	..	..	..	..	..	..	..	..
Durham.....	48	..	..	..	37	..	122	..	..	..	111	..	..	..	..	137
Arboe.....	28	..	115	108	57	..	115	..	154	..	101	..	..	125	..	111
Cushendun ..	..	..	108	..	29	20	114	..	..	..	95	..	..	126	..	119
Killarney	13	..	..	..	..	..	..	..	..	..	112	119?	100	154	..	124
Wicklow	..	..	..	100	..	..	116	..	..	..	107	106	..	124	..	119
Guernsey	..	..	..	..	..	..	96	..	..	..	91	103	..	..	..	130
Average....	27	116	112	102	38	64	113	125	140	107	109	115	114	132	140	126

[1] Never before heard in Somerset or Dorset.

on record, "never having been heard in Somersetshire or Dorset before." The large number of notices prevents these late dates from having much influence on the average date.

Lastly, the Turtle Dove is a fortnight later this year than last. It is the only species which seems to have been noticed in regular order from West to East, being heard at Usk on April 28th, and at Tacolneston May 18th, and later at the intervening stations.

So far as these notices show, birds were much earlier in their song in the first part of the year in 1887 than in 1886, and only just so in April and much later in May.

TABLE III.—BIRDS (*Continued*).

Stations.	Nesting.												
	Song Thrush.		Willow Wren.	Skylark.	Chaffinch.	Rook.			Cuckoo.		Partridge.		
	Eggs.	Young.	Eggs.	Eggs.	Eggs.	Building.	Eggs.	Young.	Ch. Note.	Left.	Pairing.	Eggs.	Young.
Babbacombe	..	..	..	..	..	..	..	..	..	..	..	..	..
Buckhorn W.	97	..	..	..	116[1]	15	..	..	..	..	..	..	..
Westward Ho.	92	..	..	123[7]	..	62	..	..	..	..	..	..	..
Wells	..	..	..	..	..	..	..	..	..	..	..	..	..
Tiverton	..	..	..	..	..	..	..	..	..	..	..	..	..
Salisbury	..	..	..	..	..	55	..	..	..	..	..	..	164
Marlborough	120	..	149	137[2]	120[3]	49	78	..	139[4]	..	55	127	..
Strathfield T.	104	..	..	..	..	..	..	124	..	..	..	116	..
Wellington Col.	..	..	..	..	..	78	..	..	..	..	..	..	..
Tunbridge W.	..	..	..	..	..	..	..	..	..	..	..	..	..
Pennington	82	..	87	127	..	..	..	99	..	184	..	135[7]	..
Henley	95	..	..	..	..	56	..	108	..	..	..	..	..
Detling	..	..	..	..	..	..	..	..	..	196	..	..	..
Ealing	..	..	..	..	..	87	..	..	..	..	..	..	..
Lewisham	..	..	..	..	..	..	..	..	..	..	..	..	..
Addington	67	..	..	..	..	67	..	..	..	..	..	119	..
Oxford	..	..	..	..	..	..	..	..	..	..	..	..	..
Cardington	..	..	..	..	..	97	..	127	..	..	..	126	..
Northampton	101	..	..	..	..	74	..	..	..	..	..	..	..
Harpenden	90	..	..	..	..	61	..	..	..	..	..	..	..
Usk	..	107	149	..	121	61	96	..	..	..	..	..	..
Hertford	..	..	..	..	..	64	..	87	155	..	..	..	..
Ware	..	..	..	..	..	..	..	..	..	..	..	..	..
Thurcaston	95	..	..	155	117	..	..	..	..	182	..	161	..
Belton	..	..	..	..	..	61	..	..	..	..	39[5]	..	..
Tacolneston	..	..	..	..	..	..	..	..	..	..	..	..	..
Hodsock	94	111	136[7]	..	131	101	..	121	..	..	29	127	152
Macclesfield	..	..	..	..	..	..	..	..	..	..	..	..	..
Tynron	..	..	..	..	..	..	..	..	..	..	..	..	..
Teesdale	..	..	..	..	..	..	..	..	..	..	..	..	..
Durham	..	..	..	..	98[8]	..	..	..	..	..	..	..	..
Arboe	96	96	..	..	106	67	..	105	137	173	..	..	..
Cushendun	..	108	..	..	..	..	..	..	..	..	..	..	..
Killarney	..	..	..	..	..	66	..	126[6]	..	..	..	..	..
Wicklow	..	..	..	..	..	55	..	..	..	..	..	..	..
Guernsey	..	..	..	..	..	..	..	..	..	188	..	..	..
Average	94	105	130	135	118	65	87	110	146	185	..	130	158

[1] Sit. [2] Young on 162. [3] Young on 136. [4] Eggs. [5] Call. [6] Fledged. [7] Nesting. [8] Building.

At Sittingbourne the Cuckoo was heard on 111, and the Swallow seen on 117. The Swallow was also *reported* as having been seen in London on 81, and at Pennington on 294. The young of the Willow Wren were observed at Marlborough on 158, and the bird was last seen at Cushendun on 220. The Brown Owl was seen at Harpenden on 31.

MIGRATION.—The Wheatear was only noticed at 2 stations, with an interval of 41 days between the two dates.

The Swallow appeared first in Guernsey on April 1st. It was seen at two other stations during the first 10 days of April, but at 8 in the next 10 days, at 8 in the last 10 days, and at 2 in May. Taking only the average dates, it spread pretty uniformly over England, appearing first on April 18th in the South, and reaching the North by the end of the month.

TABLE IV.—Birds (Supplementary).

		Marlborough.	Buckhorn Weston.	Salisbury.	Pennington.	Detling.	Northampton.	Hodsock.	Cushendun.	Wicklow.
Brown Owl	Eggs	105	..	..	..	..	..	..	..	..
	Young	140	..	..	..	..	..	..	..	..
Flycatcher	Eggs	182	154	..	..	..	..	163	..	..
Chaffinch	Eggs	142	..	..	..	..	..	..	..	..
	Last seen	..	..	..	284-'86 270-'87	..	..	..	..	..
Swallow	Eggs	147	..	161	..	..	..	134	..	..
	Young	157	..	..	..	..	..	..	..	..
	Last seen	..	..	..	..	..	..	..	..	280-'86 264-'87
House Martin	Nest	128	..	130	..	..	..	..	..	..
	Eggs	148	..	..	..	..	.	..	..	..
Sand Martin	Nest	127	..	..	..	..	..	..	..	..
	Eggs	147	..	..	..	..	..	..	..	..
Swift	Eggs	161	..	..	..	..	..	..	..	..
	Last seen	..	..	..	..	..	237	..	227	285-'86
Goatsucker	Last seen	..	..	..	211	235	..	..	..	..
Turtle Dove	Nest	122	..	..	139	..	..	..	..	..
	Young	156	..	..	..	..	..	..	..	..

The Sand Martin has been much less satisfactorily noticed, there being an interval of 53 days between the record from Salisbury and that from Addington. It must be observed, however, that this latter date is the only one in May, and if it were omitted the sequence of dates would be far more perfect. The House Martin was noticed very early at Marlborough, March 23rd, more than 3 weeks before any other place. This destroys the regular sequence of averages. It was noticed last at Ware, on May 14th, 52 days later than at Marlborough.

The Corncrake was very scarce in some parts of England: as it may be in a spot without betraying its presence, it is quite possible that some of the later dates may be incorrect. Omitting the North of Ireland, where it was earlier, it seems to have made its presence known during the first half of May.

The notices of the Swift seem to be very satisfactory. The bird, on the average, appeared in the South-west of England at the end of the first week in May, and regularly later and later till by the end of the third week it had spread over England. It is curious to note that it was very late at Usk, where other birds were often noticed earlier than elsewhere, and, latest of all, at Killarney, where it was not seen till June 3rd.

Nesting.—The nesting of the Rook, except at Buckhorn Weston, is generally considered to have begun towards the end of February, though at Hodsock not till April 11th. For a long time the birds visited their nesting places, and even once or twice one or two imagined that they might safely begin—but near Leicester the first decided commencement was not till

March 6th. They experienced a most bitter nesting season; on March 6th 27 old nests were counted, a week later there were 34 nests wholly or partially completed, and 6 days later (March 19th) no less than 61 nests. A gale blew 7 of these nests out of the trees on the 23rd, by which time eggs had been laid, but the birds cleared the nests off the ground and rebuilt them. A gale on April 6th again thinned them, and again they were rebuilt, there being 70 on April 23rd; on May 20th these 70 were reduced to 56 by another gale when 15 young were picked up, but the birds had many of them become so far fledged that they could scramble away. The cold March and these gales must have terribly destroyed the eggs or killed the young, for though only 55 were shot, hardly a young bird was seen or heard afterwards.

On the whole, therefore, migration was later than last year, whilst singing and nesting were rather earlier.

Swallows and Martins were rarely seen during the season.

ADDENDUM.

The following Notes from Mr. A. W. Preston, F.R.Met.Soc., of Thorpe Hamlet, Norwich, were received too late for incorporation in the Report:—

"The season was a remarkable one, but I was prevented from taking observations between June 17th and the end of August by a very severe illness, followed by an absence of several weeks in Scotland. The lateness of the spring appears almost unprecedented, at all events the indications are as late as those, as far as I can find, of 1837, although 1879 was nearly as late. The sudden change from winter to summer in the first week of June was remarkable, and growth was so rapid as to change a very late season to an early one by the end of July.

"In Scotland the crops were as forward by the end of July as in England, and the root crops much finer owing to occasional refreshing rains. I was told that the spring was much earlier there than here, the laburnums near the Gare Loch (Rosneath) being in full bloom by May 20th, whereas here my first date for flowering was May 29th, and full flowering June 10th. It was the most beautiful spring and summer ever remembered in Scotland."

First Flowering in the Neighbourhood of Norwich.

Anemone nemorosa...	... April 17	Syringa vulgaris ...	... May 22
Ranunculus ficaria ...	... April 7	Galium Aparine ...	... June 2
,, acris ...	... May 14	Chrysanthemum Leucanthemum ...	... May 26
Caltha palustris ...	... April 11	Symphytum officinale	... May 6
Papaver Rhœas ...	... June 12	Veronica Chamædrys	... May 14
Cardamine pratensis	... May 12	Nepeta Glechoma ...	... April 21
Sisymbrium Alliaria	... April 21	Lamium purpureum...	... Mar. 20
Draba verna	... April 3	Primula veris ...	... May 14
Viola odorata ...	... March 1	Mercurialis perennis	... April 16
Stellaria Holostea ...	... May 14	Ulmus montana ..	... April 3
Malva sylvestris ...	... June 16	Salix caprea ...	... Feb. 20
Geranium Robertianum	... June 2	Fagus sylvatica ...	... May 18
Acer Pseudo-platanus	.. May 12	Corylus Avellana ...	... Mar. 13
Æsculus Hippocastaneum	... May 24	Iris Pseud-acorus ...	... June 16
Cytisus Laburnum ...	... May 29	Narcissus Pseudo-narcissus...	Mar. 27
Lotus corniculatus ...	.. June 12	Galanthus nivalis ...	... Jan. 30
Prunus spinosa ...	... April 21	Scilla nutans ...	... May 11
Pyrus Aucuparia ...	... May 29	White pink	... June 11
Cratægus Oxyacantha	... May 26	Colchicum autumnale	... Sept. 7
Anthriscus sylvestris	... May 6		

FIRST FLOWERING IN THE NEIGHBOURHOOD OF NORWICH—*Continued.*

Winter aconite ...	... Feb. 1	Birch leaf	... April 24
Crocus	... Feb. 20	Apple blossom ...	... May 9
Primrose	... Feb. 2	Beech leaf	.. May 6
Double Daffodil ...	... Mar. 31	Oak leaf	... May 15
Hawthorn leaf ...	... Mar. 30	Ash leaf	... May 20
Horse-chestnut leaf...	... April 20	Lilac flowers... ...	... May 22
Mountain Ash leaf ...	... April 22	Orange lily	... June 12
Sycamore leaf ...	... April 20	Lilium candidum ...	...? July 9
Lime leaf	... April 12	Nightingale	... April 20

DISCUSSION.

Mr. SOUTHALL said that he had kept a record of the dates of the first flowering of plants in his garden for several years past. He thought that by observing the same plants the dates were more comparable. If the list of plants to be observed were shortened he believed that better results would be obtained.

Mr. JACKSON commented upon the desirability of fixing upon one plant in one locality. He had observed a particular plant in his garden for a long time past, and regarded the date of its flowering as an index of the lateness or forwardness of the season. Plants were fully three weeks later in blooming this year (1887) than they had been for some years past.

Mr. WHIPPLE suggested that, as the unsatisfactory character of these observations seemed to be really a question of correct identification of the species, it would be well to procure good drawings of typical plants and circulate them among the observers.

Mr. SYMONS said that Mr. Whipple's suggestion had been considered by the Committee who framed the *Instructions*, but they found that the expense of procuring such drawings, and of distributing them among the observers, would be too great. The whole question of the desirability of continuing to collect and publish these phenological observations required to be looked into.

EARTH TREMORS AND THE WIND.

BY PROF. JOHN MILNE, F.R.S., F.G.S.

(Communicated by J. W. TRIPE, M.D., Secretary.)

[Read December 21st, 1887.]

1. *Work in Italy.*—In *Nature*, Vol. XXIX., p. 456, I gave an outline of the work which had been done in Italy and in other parts of the world in the observation of earth tremors. Among the more important results which had been arrived at was the fact that microseismical disturbances are closely connected with barometrical fluctuations. The movements which take place with a barometrical depression, which are the movements most commonly observed, are in Italy called *baro-seismic* movements; while those agreeing with periods of high pressure are called *vulcano-seismic*. The relation of microseismic storms to barometric pressure is very marked during volcanic eruptions. Prof. M. S. de Rossi, the indefatigable leader in these observations, is of opinion that they are decadic, that is, they recur in periods of

ten days. This observer finds that at the Roca di Papa, 18 metres under ground, the movements are as pronounced as they are upon the surface. Vertical and intermittent movements are closely connected with seismic disturbances. In addition to these observations a number of others, though of less importance, may be found in the above-mentioned paper. Since the time that this was written considerable advances have been made in microseismical research. In 1883, with the assistance of the Minister of Agriculture and Commerce, Prof. de Rossi established an observatory in Rome, the special object of which was to study subterraneous phenomena. Every ten days this observatory issues a sheet of ten maps, on each of which the following phenomena are indicated:—

1. A set of isobars at intervals of one millimetre.
2. The intensity of microseismical movement in different parts of the peninsula.
3. The number and intensity of earthquakes.
4. The state of activity of volcanoes.
5. The state of hot springs.
6. The increase or decrease in the water of wells, &c.

The information on which these maps are founded is obtained from 27 stations distributed throughout the kingdom, at each of which there are instruments for recording earth tremors. Side by side with the maps there is a quantity of tabular matter giving details of special observations, together with the means of determining the state of seismical and microseismical activity at a selected station, or throughout the peninsula, for any particular day or for a whole decade.[1] In the *Bullettino del Vulcanismo Italiano* Prof. de Rossi from time to time gives a summary, for each decade, of what he calls the endogenous phenomena throughout the kingdom.

In the following table I have collected together the materials on which three of such summaries for the month of January 1885 are founded.

JANUARY 1885.

Decade I.	Days	1*	2	3	4	5*	6	7	8*	9	10
	Micros Means	1·42	2·23	2·32	1·68	1·77	2·26	1·70	1·63	1·33	·61
	No. of Shocks	4	3	3	3	4	3	3	2	3	4
	Max. Intensity	5°	4°	3°	1°	4°	1°	2°	3°	1°	1°
Decade II.	Days	11	12*	13	14*	15	16	17*	18	19*	20*
	Micros Means	1·44	3·07	2·59	2·15	3·07	2·86	2·41	2·08	3·37	2·59
	No. of Shocks	3	7	3	17	6	9	5	3	10	8
	Max. Intensity	2°	3°	1°	3°	3°	1°	1°	1°	3°	2°
Decade III.	Days.....	21*	22*	23	24*	25*	26*	27*	28*	29	30	31*
	Micros Means	2·03	2·13	1·74	2·66	1·59	1·83	1·74	·94	·64	·66	1·35
	No. of Shocks	19	4	4	14	19	16	9	6	1	2	6
	Max. Intensity	1°	3°	1°	8°	1°	1°	1°	1°	1°	2°	3°

The days marked with an asterisk are those indicated by Prof. de Rossi as characterised by special activity. With no other information before me than that which is contained in the table, it seems that other days might have been selected as times of maxima. Thus January 2nd, which is not indicated as

[1] The term "decade" in this paper implies a period of ten days.

a special day of activity, was apparently characterised by a greater activity than that which is recorded on the 8th, which has been selected as a day when there was a pronounced activity.

Assuming, however, that there are other reasons than the evidence of the table for making the above selection, I fail to see that the selected days of one decade have a decadical relation to those in the other decades. If two periods of ten days are each divided into three parts, it seems almost an impossibility that the periods of one decade could do anything else but nearly coincide with those of another decade. As my knowledge of the work done in Italy is necessarily of a limited nature, I recognise that my criticisms may be without good foundation, and I therefore make them for the purpose of gaining information. So far as my observations in Japan have gone, I have not hitherto recognised any connection between the earth tremors of this country and a decimal system.

The most interesting part of the Italian work is, however, the maps. Opening an atlas of these maps at random, one thing that is evident is that wherever a map is covered with isobars, which mean a steep gradient, tremors are abundant. A detailed examination of these maps renders this fact still more evident. Now a steep gradient usually indicates wind, but the state of the wind is unfortunately not shown on the maps. Further, Bertelli, who must be regarded as the author of microseismical research, together with other investigators, holds the opinion that tremors are not related to the wind. I also have stated a similar opinion, for I have found in Tokio that tremors not only occurred with a wind, but almost as often when there has only been a light breeze and even a dead calm. Since the Imperial Government of Japan have issued their admirable series of tri-daily weather maps I have been led to modify this opinion, for I now find that although tremors may accompany a calm at Tokio, at such a time there is almost invariably a strong wind blowing within a distance of from 50 to 300 miles, while if there are no tremors and a calm in Tokio there is a general calm in Central Japan. These and other conclusions have been arrived at from a consideration of the following data.

2. *General Examination of Tremor Records obtained in Tokio between January* 1885 *and May* 1886.—Calling a high barometer anything above each monthly average, and a low barometer anything below such an average, I find that with a high barometer there have been 72 days on which tremors were observed, and 143 days when they were not obsrved, while with a low barometer tremors were observed on 105 days and no tremors were observed on 104 days. The general conclusion is that we are more likely to observe tremors with a low barometer than with a high one. The table giving these results also shows that tremors are more frequent during the winter months than during the summer months.

Taking the wind velocity for each day of the above period, it is found that when the wind was high tremors were almost invariably observed, while when it was low their occurrence was relatively very few. For instance, when the wind was between 100 and 150 kilometres in the twenty-four hours tremors

were observed in 28 per cent. of the times of observation, when the wind was between 300 and 350 kilometres tremors were observed in 50 per cent. of the times of observation, while when the wind reached 700 kilometres they were always observed.

8. *Detailed Examination of the Records obtained in Tokio between January 20th and May 14th*, 1886.—As the tremor records were continuous and could be compared with each of the tri-daily weather maps, the number of observations may be regarded as being equal to three times the number of days contained in the above period.

The wind scale is as follows :—

	Metres per sec.		Metres per sec.
Force 0 = calm	= 0· — 1·5	Force 4 = gale	= 10 — 15
1 = light	= 1·5 — 3·5	5 = heavy gale	= 15 — 29
2 = moderate	= 3·5 — 6·	6 = hurricane	= 29—104
3 = strong	= 6· — 10		

The number of times that Tremors (T) were observed, and the number of times that no tremors (Nt) were recorded, with the wind in different states was as follows :—

0		1		2		3		4		5	
T.	Nt.	T.	Nt.	T.	Nt.	T.	Nt.	T.	Nt.	T.	Nt.
10	16	53	47	54	49	37	16	12	1	—	—

Putting the above results in the form of percentages :—

With the wind at 0, tremors were observed in 38 per cent. of the number of
" 1 " " " 53 " [times of observations
" 2 " " " 53·4 " " "
" 3 " " " 70 " " "
" 4 " " " 92 " " "

The average barometric gradient measured in millimetres per 120 geographical miles when tremors were observed, and when tremors were not observed, was as follows :—

With the wind at 0 the av. gradient with tremors was 2·3, without trem. 1·9
" 1 " " " 2·9 " 2·1
" 2 " " " 3·0 " 2·1
" 3 " " " 3·6 " 2·9
" 4 " " " 4·4 " 3·0

An investigation as to the number of times tremors were observed and not observed with different barometric gradients was also made.

These investigations show that tremors are more likely to occur with a high wind than with a low one—with a steep gradient than with a low gradient.

The next inquiry was respecting the presence of tremors and the absence of wind. When the wind in Tokio was calm, it was found, by reference to the weather maps, that in seven out of the ten cases when tremors

occurred there was a wind of force 3 or 4 blowing against the ranges of mountains which shelter Tokio on its northern and western sides. In the three remaining cases there does not appear to have been any wind in Central Japan which could produce tremors. These tremors were, however, very slight. In the fifty-three cases where tremors accompanied a light breeze, which occurred on 45 days, there are only ten cases which cannot be accounted for on the assumption that heavy winds at a distance were shaking the mountains which surround the Tokio plain. In the month of February especially, when gales were approaching Tokio, coming up the island from the South-west, their approach seemed to be indicated when they were at a distance of 200 or 300 miles, by tremors being felt ten hours or thereabouts before the wind arrived.

In the cases where there was a light breeze or a calm in Tokio and no tremors there was almost invariably a calm or nearly a calm in Central Japan.

When there was a wind of strength 3 or 4 in Tokio and no tremors were recorded, it seems that, if tremors are the result of wind, in three cases tremors ought to have been recorded; in three other cases the wind was local, while in the remaining cases the wind was coming in from the ocean. It must, however, not be overlooked that in the cases where tremors did occur with a high wind that the conditions were similar to those cases where tremors did not occur. Details of all these observations, which include a large quantity of tabular matter, will be published by the Seismological Society. The instrument which recorded the tremors was automatic. It is described in *Nature*, July 16th, 1885.

4. *Detailed Examination of Records obtained in Tokio between January 20th and November 30th*, 1885.—Between January 20th and November 30th, 1885, the Meteorological Department of Japan issued 945 tri-daily Weather Charts. The scale indicating the force of wind which is used upon these maps ranges from 0 to 6, 6 being a hurricane. By "no wind" in Central Japan I mean that the force of the wind as recorded at stations within 200 or 300 miles of Tokio nowhere exceeds 2. If at any of the eleven stations which are fairly evenly distributed within the above limits the wind has a force of 3 or 4, the weather has been regarded as windy. It is evident that this classification will in many instances be unsatisfactory, as, for instance, where we have a strong local wind at one station and nearly a dead calm at all the others. In such a case the observation would fall under the head of "windy," while so far as Central Japan was concerned it was practically calm. This has led me to subdivide the windy days into groups where the wind was of moderate intensity and where the wind was local.

Comparing the 945 maps thus subdivided with the occurrence of tremors I obtain the following results:—

1. With no wind and no tremors there were 651 cases.

2. With no wind and tremors there were 51 cases, which may be subdivided as follows:—

(*a*) Tremors possibly of subterraneous origin, 26 cases.

(*b*) Tremors accompanying barometrical depressions, 8 cases.

(*c*) Tremors which might be due to wind that had been blowing a few hours previously, 17 cases.

8. With wind and no tremors there are 60 cases, which may be subdivided into

(*a*) Where tremors ought to have occurred - - -	9	cases
(*b*) Cases where it is doubtful whether tremors ought to have occurred, the wind being moderate - - -	51	,,
4. With wind and tremors - - - - - -	65	,,
5. With local wind and no tremors - - - - -	101	,,
6. With local wind and tremors - - - - -	17	,,
Total - - - - - - - - -	945	

From the above we see that tremors have been recorded 133 times. An obvious explanation for 65 of these cases (50 per cent.) is that they were produced by strong winds which were blowing at the times of observation. These tremors are well marked and of long duration. 34 cases (17 + 17) or 25 per cent. of the remaining cases might have been produced either by wind which had been blowing a few hours previous to the time of observation, or to strong local winds. The remaining 34 cases (26 + 8) or 25 per cent. may possibly be of subterraneous origin. These latter tremors are usually of short duration, not exceeding one or two hours.

That earth tremors may in great measure be due to wind receives great support from the fact that when there is a calm in Central Japan it is seldom that tremors are observed. From the 34 certain cases (26 + 8) where tremors which are usually slight have accompanied calms, out of 685 observations (651 + 34), we may say that calms have been accompanied by tremors in less than 5 per cent. of the times of observation.

To test the results which are indicated in the preceding pages, I asked Colonel H. S. Palmer, R.E., to determine from a series of weather maps (Jan. 20th to May 18th, 1886) the nature of the tremor records which had been obtained in Tokio, he not being acquainted with these records. The rules which were to guide him were as follows:—1. With a general calm in Central Japan tremors are rarely observed. 2. With a wind in Tokio, or with a calm in Tokio, but with a heavy wind blowing against the hills which at a distance of from 40 to 100 miles shelter the Tokio plain, there may be tremors.

The result of Colonel Palmer's examination was as follows:—In 35 instances as to whether there had been tremors or no tremors it was doubtful. In 30 of these cases I found that there had been tremors. In 57 instances Colonel Palmer reported that tremors ought to have been recorded. In 54 cases (94 per cent.) he was absolutely correct, there having been tremors which were very marked. In the remaining 165 cases it was reported that there were no tremors. He was correct in 74 cases, while in 91 cases where he was wrong there had been slight tremors. Had Colonel Palmer been

acquainted with the whole of the results which had been arrived at respecting the relationship of earth tremors to wind, his results would have come still nearer to the truth.

General Conclusions. The conclusions I wish to refer to are those based upon the preceding investigations. General conclusions which have been arrived at respecting the occurrence of tremors in relation to lunar and solar motions and other phenomena have been detailed in a paper on earth tremors published in the *Transactions of the Seismological Society*, Vol. VII. Part 1.

1. Earth tremors are more frequent with a low barometer than with a high barometer, but even with a low barometer it may often happen that tremors are not observed.

2. With a high barometric gradient tremors are almost always observed, but when the gradient is small it is seldom that tremors are visible.

3. The stronger the wind the more likely it is that tremors should be observed.

4. When there has been a strong wind and no tremors the wind has usually been local, of short duration, or else blowing inland from the ocean. We must not, however, overlook the fact that such winds are occasionally accompanied by tremors.

5. When there has been little or no wind in Tokio and yet tremors have been observed, in most cases there has been a strong wind in other parts of Central Japan. In the case of winds working up from the south-west this has been very marked, tremors being felt in Tokio several hours before its arrival. When neither wind nor tremors are to be observed in Tokio there is usually a general calm in Central Japan.

6. From 75 to 80 per cent. of the tremors observed in Tokio may be accounted for on the supposition that they have been produced either by local or distant winds.

7. The only connection between earth tremors and earthquakes in Central Japan is that they are both more frequent about the same season.

It now remains to discuss the probability of earth tremors being produced in the manner which these results indicate. Among the various objections which may be brought forward to show that earth tremors are subterraneous phenomena, and are not surface disturbances produced by the wind, the following may be mentioned.

In Italy, where more has been done for microseismical investigation than in any other country, the general opinion, based upon observationn which, I regret to say, I have not the means of consulting, is that tremors are not related to the wind. Prof. de Rossi finds tremors as marked at Roca di Papa, 18 metres under ground, as he finds them on the surface. Many tremors are undoubtedly connected with earthquakes.

In Japan, however, I do not observe any connection with earthquakes more than that each are most frequent during the same seasons.

The fact that 25 per cent. of the tremors I have observed cannot be accounted for on the supposition that they are produced by wind, suggest

the possibility that in all the other cases where tremors appear to be connected with a local or a distant wind may be accidental coincidences between the time of subterraneous activity and atmospheric disturbance, it being assumed that in 80 days out of every 100 that wind is blowing somewhere in Central Japan.

In support of the supposition that many earth tremors are superficial disturbances, we may refer to the universal experience that heavy winds will deflect chimneys and shake trees and buildings. These reacting at their foundations shake the ground, and that local winds may in this way produce local tremors is a fact which I think will be generally admitted. To show that tremors may be propagated to the distance of from 100 to 800 miles is however a more difficult matter. We know that on ordinary ground a gentle stamp may be seen reflected as tremors in a dish of mercury at a distance of 150 feet. The movement of a railway train may be recorded by its tremors at the distance of a mile. If the tremors produced by quickly rocking a block of wood on ordinary ground are observed at some distance reflected from a surface of mercury, it appears that there is a short interval in time before they reach their maximum. May not this be an indication that the distance to which tremors originating from a given source may spread is partly due to the length of time that the force producing them is in action? From five days' observation with a tremometer on the top of Fujisan (12,400 feet), during which time a strong wind was blowing, I observed not only tremors of considerable amplitude but also what may have been a deflection in the vertical. On the assumption that this mountain was made of brick and it was exposed to a wind pressure of 40 lbs. on the square foot, Prof. Alexander calculated that the deflection ought to have been greater than that which was observed. With these facts before us it does not seem improbable that a gale of wind blowing against the side of a range of mountains 5,000 to 7,000 feet in height should produce a disturbance upon their leeward side extending many miles. The observations which I have made certainly indicate that such disturbances exist, and if they are confirmed it will not be long before meteorological observatories will regard tremometers as important additions to their equipment.

DISCUSSION.

Mr. HARRIES said he thought Prof. Milne had been rather misled by Prof. de Rossi's pressure charts, showing differences of only one millimetre, into considering the barometric gradient as steep, simply because he was more accustomed to deal with the Japanese charts, which are generally drawn for differences of 5mm. Owing to the Italian system of drawing isobars for very small differences, it results in an optical illusion to say that "whenever a map is covered with isobars, which mean a steep gradient, tremors are abundant." Having examined the Italian Daily Weather Reports for January 1885, in connection with the table of microseismic shocks for the same period, he (Mr. Harries) considered there was little to remark in the first decade, but from the 11th to the 18th there was a disturbance over the Gulf of Lyons, the minimum reading being on the 14th 29·4 ins., when 17 shocks were recorded, but otherwise the period was not marked by any special activity. On the evening of the 18th the cyclonic disturbance passed away to the southern side of the Mediterranean, and

for the remainder of the month the conditions of pressure over Europe were decidedly anticyclonic, the maximum pressure being about 30·8 ins., and the mean centre of the area covering the Austrian Empire. It was curious to observe that Prof. de Rossi marked the period from the 19th to the 28th as characterised by special activity, the shocks averaging 12 per day, or double the average between the 11th and 18th. Mr. Harries was more inclined to dwell upon this phase of the question because he had recently endeavoured to connect the preponderating frequency of colliery explosions under anticyclonic conditions of pressure to another cause than the mere liberation of small quantities of gas with a falling barometer, viz. with earth movements due to areas of high barometer. Dr. Knott, another Japanese seismologist, rather favoured the idea that the great winter anticyclones over the continents are important, if not the main, factors in the production of earthquakes, but he did not attach much importance to the effect of the wind. Prof. Darwin had also dealt with the probable influences of absolute changes of pressure on the earth's crust, and assigned a possible change of level of from 3 to 4 ins., with a barometric variation of 2 ins. There was little or no evidence in the paper to show that the force of the wind exerted any appreciable effect on the earth, the Italian records for the period adopted showing that from January 18th to 31st not a dozen out of about five hundred observations registered a velocity exceeding 30 kilometres per hour (a gentle breeze), the great majority being calms and light airs. Even in Japan Prof. Milne's own statistics showed that when the wind averaged from 4 to 6 kilometres per hour, or 100 to 150 kilometres in the day—practically a calm by the English scale—nearly one-third of the observations were accompanied by tremors; when the velocity was 12 to 15 kilometres per hour, or a light air, one half the observations were accompanied by tremors, and all observations when the average velocity was 30 kilometres per hour, a gentle breeze, were marked by tremors. These results seemed rather to negative Prof. Milne's idea that the force of the wind had much, if any, influence, as it could scarcely be contended that wind forces such as those quoted were sufficient to shake even the most tottering of chimneys, much less such solid and permanent structures as the celebrated Fujiyama mountain.

Mr. RUPERT SMITH said that he had spent seven weeks in Japan, and during the whole of that time he experienced one earth tremor at least on every day. He could not agree that these tremors were due to the pressure of strong winds against the mountains.

Mr. LECKY said that he could not see how these earth movements had any connection either with the force of wind or the pressure of the atmosphere. He believed the simple cause of earthquakes was the formation of steam at a great depth in the earth.

Mr. SYMONS said that the North of England Institute of Mining Engineers had brought the question of Earth Tremors prominently before the Manchester Meeting of the British Association, and, as a result of a consideration of the matter, an influential Committee had been formed, composed of men interested in inquiries of this nature. It was intended to establish tremometers, or some similar instruments, at various places throughout this country.

Mr. Symons then drew attention to the explosion of a bolide (which was at first mistaken for an earthquake shock) on November 20th, at 8.20 a.m., over Central England, and showed by means of a map the large area over which the noise of the explosion was heard and the vibration felt.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

NOVEMBER 16TH, 1887.

Ordinary Meeting.

WILLIAM ELLIS, F.R.A.S., President, in the Chair.

CHARLES EDMUND DE BERTODANO, Assoc.M.Inst.C.E., Manila;
WILLIAM A. BOWEN, 21 Dalhousie Street, Rangoon, Burma;

FREDERICK JOHN BRODIE, 41 Ouseley Road, Balham, S.W.;
THEOPHILUS BULKELEY HYSLOP, M.B., Royal Albert Asylum, Lancaster;
H. H. MCMINNIES, Adelaide, South Australia; and
CAPT. THOMAS C. NEWTON, s.s. "Minia," Halifax, Nova Scotia,
were balloted for and duly elected Fellows of the Society.

The following letter from the Home Secretary was read:—

Whitehall, 4th July, 1887.

Gentlemen,

I have had the honour to lay before The Queen the loyal and dutiful Address of the President, Council and Fellows of the Royal Meteorological Society on the occasion of Her Majesty attaining the Fiftieth Year of Her Reign; and I have to inform you that Her Majesty was pleased to receive the same very graciously.

I have the honour to be, Gentlemen,
Your obedient Servant,
HENRY MATTHEWS.

The Secretaries of the
Royal Meteorological Society.

The following Papers were read, viz.:—

"The use of the Spectroscope as a Hygrometer simplified and explained." By FREDERIC W. CORY, M.R.C.S., F.R.Met.Soc. (The publication of this Paper is deferred.)

"On the cause of the Diurnal Oscillation of the Barometer." By ROBERT LAWSON, LL.D. (p. 1.)

"Rainfall on and around Table Mountain, Cape Town, Cape Colony." By JOHN G. GAMBLE, M.A., M.Inst.C.E., F.R.Met.Soc. (p. 12.)

DECEMBER 21ST, 1887.

Ordinary Meeting.

WILLIAM ELLIS, F.R.A.S., President, in the Chair.

REV. RICHARD BARKER, The Heath, Uttoxeter;
WILLIAM W. DAY, M.D., Church Street, Lower Edmonton;
HENRY NEWTON DICKSON, 38 York Place, Edinburgh;
HENRY HARRIES, Rosebank, Hounslow;
PERCY SHAW JEFFREY, B.A., Roselle, Mount Ephraim, Tunbridge Wells;
HERBERT ALISON JOHNSTONE, 3 Greek Terrace, Stockport; and
JEREMIAH WOLSTENHOLME, Town Hall, Blackpool,
were balloted for and duly elected Fellows of the Society.

MR. J. S. HARDING and MR. H. S. WALLIS were appointed Auditors of the Society's Accounts.

The following Papers were read, viz.:—

"The Mean Temperature of the Air at Greenwich from September 1811 to June 1856." By HENRY STORKS EATON, M.A., F.R.Met.Soc. (p. 15.)

"Report on the Phenological Observations for 1887." By the REV. T. A. PRESTON, M.A., F.R.Met.Soc. (p. 40.)

"Earth Tremors and the Wind." By PROF. JOHN MILNE, F.R.S., F.G.S. (p. 64.)

"Pressure and Temperature in Cyclones and Anticyclones." By PROF. H. A. HAZEN. (p. 74.)

CORRESPONDENCE AND NOTES.

PRESSURE AND TEMPERATURE IN CYCLONES AND ANTICYCLONES.[1] By Prof. H. ALLEN HAZEN, of the Signal Office, Washington, U.S.A. (Read before the Royal Meteorological Society, December 21st, 1887.) (Abstract.)

THE changes in these elements at sea-level are perfectly well known, but when we consider their fluctuations at some height above the earth's surface, we find opinions very diverse. Theoretically, they should be about the same below and above to a moderate height, but it is thought by some that the higher temperature at the low levels in a cyclone will expand the air upward, and we shall finally reach a plane called the neutral plane, or that of no change; and above that point the pressure gradually rises. It is very difficult to determine just the height of this plane in each storm, and, so far as I know, no attempt has been made to fix it even approximately. Observations at the highest stations show the fall in pressure very nearly the same as at sea-level, so that the existence of such a plane may be considered highly imaginary.

It is now well known that the minimum pressure on a mountain does not coincide with the passage of a storm centre over the station, but lags considerably behind it. The amount of this lagging is not definitely known, but depends upon the height of the mountain and surrounding topography. On Mt. Washington, 6,279 ft. above sea-level, the lagging amounts to about 11 hours, that is, the minimum pressure at the summit occurs 11 hours after the centre of the storm has passed over it. A more recent investigation has established the fact that there is very nearly the same lagging in the passage of a high pressure. Prof. Loomis was the first to point out this interesting fact in the case of storms, and it was thought for some time that this indicated an actual inclination of the axis of the storm, but this supposition was soon found to be entirely erroneous. I showed in discussing the records that the lagging was due to the fall in temperature which always quickly follows a storm. More recently I have determined that the effect in the case of high pressure is due to the rise in temperature which immediately follows a high pressure area. It is easy to see that in the first case the low temperature contracts the air below the summit, and while the pressure rises at the base, it continues to fall at the summit till the effect of the low temperature is overcome by the rising pressure.

We have here then a very simple explanation of the peculiar results obtained by M. Dechevrens and Dr. Hann. If we wait till the lowest pressure has occurred at the summit of a mountain, the temperature has already fallen greatly; and, on the other hand, when the highest pressure has reached the summit, the temperature has risen very much, so that

[1] This Paper has been published in full in the *American Meteorological Journal* for October 1887.

we seem to obtain a high temperature with an anticyclone and low temperature with a cyclone. I am well aware that Dr. Hann uses only the expressions "low pressures" and "high pressures" in his discussion, but they may well be applied to cyclones and anticyclones, and those who have quoted from him have invariably so applied them. In Table I. I have placed in parallel vertical columns, for direct comparison, the results obtained in the various discussions.

TABLE I.

VARIATIONS OF PRESSURE AND TEMPERATURE WITH HEIGHT.

Highest to Lowest Pressure at Summit.

Pic du Midi (Dechevrens), 7,763 feet.		Mt. Washington, 6,280 feet.		Sonnblick (Hann), 10,140 feet.	
Pressure.	Temp.	Pressure.	Temp.	Pressure.	Temp.
Ins.	°	Ins.	°	Ins.	°
21·73	23·4	24·10	27·9	20·84	18·1
21·58	28·0	23·94	19·8	20·68	13·6
21·42	24·3	23·78	16·7	20·52	9·0
21·26	19·8	23·62	14·7	20·42	5·5
21·10	16·3	23·46	11·8	20·32	5·4
20·95	15·1	23·31	5·5	20·25	7·0
20·79	12·0	23·15	+3·9	20·20	1·6
20·63	7·7	22·99	—2·0	20·14	1·6
20·47	5·2	22·83	0·0	19·95	3·2
		22·68	—7·4		
		22·52	—10·3		

There is a great uniformity in these results, showing low temperature with low pressure, and *vice versâ*. I have studied in a similar manner the fluctuations of temperature and pressure at Mt. Washington, but have obtained nothing like the variation found by M. Dechevrens. It is probable that he has combined only the more marked instances in his table, and in fact he says he found a large number of exceptions. From a study of 4,000 observations, I found the temperature on the summit 8° to 5° lower at the lowest pressure on the summit than at the highest pressure.

When we consider the passage of the storm centre over the summit, however, the result is unmistakeable. From a study of all the observations two days before and after the passage of a storm centre, comprising about 4,000 at the summit, I found at the centre of the cyclone the temperature 17°·6 Fahr., and at the centre of the anticyclone 0°·8 Fahr. This result is quite extraordinary when compared with that just adduced, and I give here a table (II.) showing the means of the observations. I have given the results of observations during forty anticyclones and forty cyclones in groups of ten.

I have projected each of these groups of ten in curves, and have found that they are almost identical, so that we may conclude that the following laws are quite firmly established.

TABLE II.

MEAN PRESSURE AND TEMPERATURE AT BURLINGTON AND MOUNT WASHINGTON FROM 2 DAYS BEFORE TILL 2 DAYS AFTER THE PASSAGE OF AN ANTICYCLONE.

Day.	Two days before.					One day before.					Centre.					One day after.					Two days after.				
Time.	7 a.m.	11 a.m.	3 p.m.	7 p.m.	11 p.m.	7 a.m.	11 a.m.	3 p.m.	7 p.m.	11 p.m.	7 a.m.	11 a.m.	3 p.m.	7 p.m.	11 p.m.	7 a.m.	11 a.m.	3 p.m.	7 p.m.	11 p.m.	7 a.m.	11 a.m.	3 p.m.	7 p.m.	11 p.m.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+
PRESSURE.	·78	·75	·76	·79	·80	·82	·83	·84	·94	1·03	1·16	1·18	1·12	1·10	1·05	·94	·85	·74	·70	·64	·58	·57	·58	·65	·70
	·68	·67	·64	·68	·67	·71	·78	·81	·85	1·05	1·25	1·29	1·22	1·22	1·18	1·06	1·00	·88	·80	·72	·66	·66	·64	·65	·63
Burlington	·76	·75	·71	·72	·75	·84	·90	·92	·98	1·01	1·09	1·07	1·00	·99	·96	·91	·86	·81	·81	·79	·70	·68	·66	·72	·71
	·74	·72	·69	·71	·71	·80	·85	·87	·99	1·07	1·21	1·22	1·18	1·16	1·09	·99	·82	·74	·71	·66	·68	·75	·76	·82	·83
	·74	·72	·70	·72	·73	·79	·84	·86	·94	1·04	1·18	1·19	1·13	1·12	1·07	·98	·88	·79	·76	·70	·66	·66	·66	·71	·72
	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+
	·56	·59	·60	·61	·62	·62	·59	·56	·58	·60	·74	·81	·83	·86	·86	·80	·76	·68	·66	·61	·51	·49	·43	·44	·45
Mount	·37	·37	·36	·38	·38	·34	·34	·34	·39	·45	·60	·71	·75	·78	·80	·75	·70	·64	·63	·57	·46	·45	·44	·46	·47
Washing-	·52	·52	·50	·49	·49	·51	·54	·54	·57	·59	·65	·68	·68	·70	·70	·71	·68	·67	·69	·68	·64	·58	·55	·56	·55
ton	·44	·42	·36	·33	·34	·32	·35	·36	·38	·42	·52	·59	·61	·63	·64	·56	·50	·46	·44	·42	·38	·38	·38	·38	·42
	·47	·48	·46	·45	·46	·45	·45	·45	·48	·52	·63	·70	·72	·74	·75	·70	·66	·61	·60	·57	·50	·48	·45	·46	·47
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
	107·6	107·6	105·8	105·8	105·8	100·4	96·8	96·8	91·4	86·0	80·6	84·2	87·8	87·8	91·4	96·8	100·4	102·2	105·8	109·4	107·6	105·8	102·2	100·4	98·6
	77·0	78·8	86·0	73·4	71·6	73·4	66·2	62·6	57·2	57·2	50·0	51·8	55·4	57·2	59·0	69·8	75·2	77·0	84·2	86·0	91·4	89·6	80·6	89·6	91·4
TEMPERA-	91·4	93·2	93·2	91·4	89·6	89·6	82·4	78·8	78·8	80·6	77·0	77·0	82·4	82·4	82·4	87·8	89·6	95·0	95·0	96·8	100·4	102·2	96·8	96·8	98·6
TURE.	75·2	71·6	69·8	69·8	71·6	69·8	69·8	68·0	66·2	59·0	66·2	55·4	55·4	55·4	59·0	66·2	66·2	69·8	73·4	75·2	77·0	73·4	73·4	73·4	73·4
Burlington	87·8	87·8	89·6	86·0	84·2	82·4	78·8	77·0	73·4	71·6	68·0	68·0	69·8	71·6	73·4	80·6	82·4	86·0	89·6	91·4	93·2	93·2	87·8	86·0	86·0
	69·8	68·0	68·0	68·0	68·0	64·4	60·8	59·0	55·4	51·8	46·4	50·0	53·6	57·2	64·4	71·6	73·4	77·0	80·6	84·2	80·6	77·0	73·4	68·0	62·6
	51·8	50·0	50·0	51·8	50·0	46·4	37·4	32·0	23·0	21·2	24·8	30·2	33·8	37·4	42·8	53·6	60·8	60·8	64·4	66·2	64·4	60·8	62·6	62·6	62·6
Mount	51·8	57·2	53·6	55·4	55·4	53·6	50·0	44·6	41·0	41·0	41·0	44·6	48·2	53·6	53·6	62·6	64·4	69·8	73·4	77·0	78·8	75·2	75·2	68·0	62·6
Washing-	48·2	48·2	44·6	42·8	39·2	32·0	28·4	30·2	28·4	19·4	12·2	15·8	21·2	23·0	33·8	44·6	48·2	53·6	53·6	53·6	51·8	44·6	37·4	39·2	41·0
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TABLE II.—*continued.*

MEAN PRESSURE AND TEMPERATURE AT BURLINGTON AND MOUNT WASHINGTON FROM 2 DAYS BEFORE TILL 2 DAYS AFTER THE PASSAGE OF A CYCLONE.

Day.	Two days before.					One day before.					Centre.					One day after.					Two days after.				
Time.	7 a.m.	11 a.m.	3 p.m.	7 p.m.	11 p.m.	7 a.m.	11 a.m.	3 p.m.	7 p.m.	11 p.m.	7 a.m.	11 a.m.	3 p.m.	7 p.m.	11 p.m.	7 a.m.	11 a.m.	3 p.m.	7 p.m.	11 p.m.	7 a.m.	11 a.m.	3 p.m.	7 p.m.	11 p.m.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+	29+
PRESSURE.	·93	·93	·93	·88	84	·77	·71	·61	·57	·50	·38	·35	·34	·44	·52	·75	·81	·81	·84	·85	·83	·82	·80	·84	·84
	·79	·82	·81	·85	·83	·77	·62	·63	·56	·48	·37	·43	·44	·53	·58	·74	·79	·78	·85	·86	·88	·88	·81	·79	·74
Burlington	·82	·80	·74	·74	·75	·74	·72	·67	·66	·61	·46	·42	·38	·42	·40	·46	·49	·52	·58	·62	·72	·73	·70	·72	·73
	·98	1·00	1·00	1·04	1·04	1·06	1·06	·96	·89	·79	·54	·51	·47	·51	·52	·61	·67	·71	·83	·91	·99	·99	·95	·97	·95
	·88	·89	·86	·88	·86	·84	·78	·72	·67	·60	·44	·43	·41	·48	·50	·64	·69	·70	·78	·81	·86	·86	·82	·83	·82
	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+	23+
	·72	·74	·72	·73	·72	·67	·64	·55	·51	·44	·32	·24	·18	·19	·21	·32	·40	·47	·54	·59	·59	·59	·60	·60	·59
	·44	·40	·40	·44	·44	·48	·47	·42	·40	·32	·17	·14	·11	·16	·21	·28	·34	·36	·39	·43	·47	·49	·48	·52	·48
Mount Washington.	·59	·59	·58	·56	·55	·58	·57	·56	·54	·53	·43	·36	·32	·31	·30	·22	·23	·22	·24	·27	·35	·38	·39	·40	·41
	·39	·44	·45	·48	·50	·55	·61	·60	·59	·56	·42	·31	·21	·13	·16	·11	·17	·16	·18	·21	·30	·34	·34	·38	·40
	·54	·54	·54	·55	·55	·57	·57	·53	·51	·46	·34	·26	·20	·20	·22	·23	·28	·30	·34	·38	·43	·45	·45	·48	·47
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
	96·8	98·6	98·6	100·4	100·4	104·0	104·0	104·0	104·0	105·8	104·0	98·6	93·2	89·6	87·8	80·6	82·4	84·2	84·2	84·2	86·0	87·8	89·6	89·6	89·6
	75·2	73·4	75·2	75·2	75·2	80·6	84·2	77·0	82·4	82·4	80·6	75·2	71·6	68·0	66·2	60·8	64·4	68·0	66·2	68·0	68·0	69·8	75·2	75·2	77·0
TEMPERATURE.	78·8	80·6	80·6	82·4	84·2	87·8	91·4	93·2	91·4	91·4	96·8	96·8	98·6	100·4	102·2	98·6	95·0	89·6	89·6	86·0	84·2	84·2	86·0	86·0	86·0
	57·2	59·0	60·8	60·8	59·0	59·0	62·6	66·2	68·0	73·4	82·4	78·8	75·2	73·4	73·4	69·8	64·4	60·8	57·2	53·6	48·2	51·8	55·4	57·2	59·0
Burlington	77·0	78·8	78·8	78·8	78·8	82·4	86·0	86·0	86·0	87·8	91·4	87·8	84·2	82·4	82·4	77·0	77·0	75·2	75·2	73·4	71·6	73·4	77·0	77·0	78·8
	60·8	66·2	66·2	68·0	71·6	77·0	82·4	82·4	82·4	84·2	82·4	77·0	68·0	59·0	50·0	35·6	35·6	37·4	42·8	48·2	55·4	57·2	59·0	57·2	57·2
	46·4	41·0	42·8	39·2	41·0	48·2	51·8	57·2	59·0	59·0	57·2	51·8	42·8	39·2	35·6	28·4	30·2	30·2	30·2	32·0	35·6	41·0	44·6	50·0	50·0
Mount Washington.	57·2	62·6	66·2	64·4	62·6	62·6	62·6	62·6	64·4	66·2	69·8	64·4	64·4	66·2	62·6	55·4	55·4	48·2	46·4	46·4	41·0	41.0	42·8	44·6	46·4
	17·6	15·8	21·2	21·2	24·8	28·4	37·4	39·2	44·6	51·8	62·6	60·8	46·4	42·8	35·6	28·4	21·2	19·4	14·0	8·6	1·4	3·2	10·4	14·0	17·6
	46·4	46·4	50·0	48·2	50·0	53·6	59·0	60·8	62·6	64·4	68 0	64·4	55·4	51·8	46·4	37·4	35·6	33·8	33·8	33·8	33·8	35·6	39·2	41·0	42·8

1st. In both cyclones and anticyclones the pressure lags from 10 to 11 hours at the summit of Mt. Washington.

2nd. The temperature change at the base precedes very slightly the pressure change, but at the summit the change occurs nearly 24 hours earlier.

3rd. The temperature appears to be a very little earlier at the summit than at the base, and certainly varies much more rapidly at the former.

4th. In a cyclone, the difference in temperature between base and summit is less than the mean before the storm, but the difference rapidly increases after the centre has passed. Just the contrary is true in an anticyclone.

5th. The total fall in pressure in a cyclone at the summit very nearly equals that at the base, and likewise the rise in an anticyclone.

6th. The fluctuation of temperature, that is from the highest to the lowest, at the summit is double that at the base in a cyclone, but it is only a little greater in an anticyclone.

On the Passage of a Whirlwind over the Ship "Bactria," of Liverpool. By Capt. R. J. Balderston.

On July 27th, 1887, in latitude 3° South, and longitude 92½° East, seeing to windward a long dark cloud which bore the appearance of a heavy squall, we shortened sail until only the topsails, jib, and fore-topmast-stay-sail remained set. The wind was from South-west, and the wind and weather for the previous 24 hours had been light and moderate. As the cloud approached the vessel the formation of white tops upon the waves showed that it was bringing with it a strong breeze. *All at once*, right abeam of the vessel, and not more than three ships' lengths away (900 feet), the action of a whirlwind showed itself upon the water in the shape of a whirling lot of spray. The diameter of the whirl was not less than 30 feet, and its height increased in the few seconds during which it lasted from a few inches in the centre, to 7 or 8 feet on the outer edge. About 8 feet would be its height when it struck the vessel's side, against which it broke, and was then carried as a shower of spray across the vessel's deck, over the boats which lie on skeads between the mizen and main masts.

After its passage over the vessel it twice formed a partial whirl for a few instants only upon the water to leeward, and then disappeared, leaving a small calm space upon the surface, which the wind soon ruffled over; the whirlwind's power to cause re-rotation of the water having apparently been destroyed during its passage over the ship.

As the spray from the whirl flew over the vessel a very heavy gust of wind struck the ship, and we let go the topsail halyards, the upper and lower topsails and other clewed up sails flapping heavily twice or thrice as if suddenly taken aback and as suddenly filled again.

When struck, the ship went over to an angle of about 35° from the perpendicular. The rotation of the whirl was to the right hand, and it appeared to be *dragged* across the sea in a series of jerks,[1] or rather by a *long pull* and a *short stoppage*, three of these pulls and stoppages bringing it from its place of formation to the ship's side.

The wind from the squall blew the nearest approaching tops of the whirling spray backward and against the circle of rotation.

If the vessel had not been prepared for a heavy squall she would most likely have lost all her sails and many spars. The whirlwind only lasted a few seconds, the squall of which it formed a part lasted about twenty minutes.

[1] Upon the previous voyage, while in the Indian Ocean, I also noticed this kind of jerking dragging motion during the passage of two whirls, one of which eventually formed itself into a large waterspout; the other one was lost to sight in some heavy rain.

St. Elmo's Fire, at Weymouth, January 3rd and 4th, 1873. By T. B. Groves, F.C.S., F.R.Met.Soc.

An incidental reference to this phenomenon in a recent Paper on Ball Lightning suggests to me the propriety of putting on record two occasions of its appearance in Weymouth Harbour. I quote the following from my note book :—

"The phenomenon, called by sailors Corposants, was observed on the quarter of the Watch-house boat on Friday, January 3rd, 1873, at 9.30 p.m., and on January 4th at 11.30 p.m., lasting on each occasion more than an hour." The weather was very squally and heavy showers fell at intervals.

My informants told me that it had never occurred before in the harbour to their knowledge, but most of them had frequently seen it in foreign parts.

Hann's "Atlas der Meteorologie."

This is a separate issue of the third section of the new edition of *Berghaus' Physical Atlas*, and it is a work which no meteorologist should be without, if he intends to study climatology. It consists of twelve maps, each of which comprises at least four maps of smaller scale. The whole series are introduced by a carefully written explanation of the mode of preparation and the purport of each map, which is in itself a condensed epitome of climatology.

Map I. gives the annual isotherms, and on a smaller scale, the annual isabnormals, the equal range lines, and the North Polar annual isotherms. Maps II. and III. give January and July isotherms respectively, and the smaller maps show the isabnormals for January and July, the winter and summer isotherms about the North Pole, the January isotherms of South America, and the May isotherms of Southern Asia. Map IV. gives the isotherms for Europe for January, July, and the year, and in addition the advance of spring over Europe, according to Hildebrandsson. Map V. gives three maps for North America to correspond with those for Europe, and the January isotherms of the Eastern States. Map VI. gives the yearly isobars; and in addition smaller charts showing the annual isobars for Europe, a chart of the average depth of barometric minima, and one of the mean range of the barometer over the globe. Maps VII. and VIII. give isobars and wind for January and July respectively, and also North Polar isobars, as well as isobars for Europe for the same months, the sheet being completed by maps showing the mean monthly range for winter and summer. Map IX. gives isobars and isotherms for Europe for abnormal seasons, viz. December 1879 and December 1880. Map X. shows the tracks of barometric minima over the Atlantic, with a number of small charts giving conditions of various Föhn and Bora storms, &c. Map XI. gives the distribution of rain over the globe, with various local rain maps, such as the United States, India and Burma, and Europe. Map XII., the last, is by Dr. Köppen. It shows the distribution of rain as to seasons, with, for Europe, a map of the yearly period of rain frequency, and of the period of the annual maxima of quantity.

Boguslawski's and Krümmel's "Handbuch der Ozeanographie."

This book forms part of Prof. Ratzel's *Bibliothek Geographischer Handbücher*. The work was originally entrusted to Dr. von Boguslawski, who by ill-health was prevented from finishing more than the first volume, on the form and the physical and chemical constitution of the oceans. On his death, in 1884, Prof. Zöppritz was requested to take up the incomplete work, but he also died, in 1885, and then Dr. Krümmel was persuaded to undertake the task. Volume II. is the result, which deals with the movements or circulation of the water. Dr. von Boguslawski's volume is very poorly illustrated, having only fifteen diagrams, and no charts, for 400 pages. The author for the most part contents himself with citing various authorities, without much attempt to frame a connected history. The volume is therefore pre-eminently a book of reference for facts.

Dr. Krümmel's volume is more closely reasoned, and is much more fully illustrated. Chapter I. deals with waves of all sorts, chapter II. with tides and their theories. In chapter III., on the vertical circulation of the water, the author maintains the view that the cold water on weather shores, like that noticed by the late Admiral Sir F. W. Grey on the West Coast of Africa, is produced by winds blowing away the surface warm water, and thereby forcing the colder layers from below to rise. This action, which he calls *auftrieb*, "up-pushing," has been described by the Meteorological Office in its work on the Cape of Good Hope, at page 21. Chapter IV., nearly one-half of the book, is devoted to currents, firstly—their general theory, and, secondly, their phenomena in the different oceans.

The work is very useful, and it would be very desirable were it translated.

The authors, with a conscientiousness which is not common in this country, endeavour to give, like Dr. Schmid in his *Meteorologie*, the exact authority for almost every statement.

ABERCROMBY'S "WEATHER."[1]

MANY books have been written on Storms and Climate, and on Meteorology in general, but none on everyday Weather. The whole of Mr. Abercromby's work is devoted to Weather, both in the tropics and in the temperate zone. The book is a very valuable one, as it is not a mere compilation of existing knowledge, but includes the results of many of the author's original and unpublished researches.

The work is divided into two parts, viz. Elementary and Advanced. The Elementary portion includes a chapter on popular weather prognostics, which are explained by means of synoptic charts. Clouds and cloud-prognostics are also fully described. In the Advanced portion the author goes more deeply into the details of isobars, and explains how they are the product of different forms of atmospheric circulation. Barograms and other meteorological records are next described, and the author shows how the changes in the shape of the isobars, as seen on two successive charts, indicate the sequence of weather as observed in any one place.

The relation of both the velocity and direction of the wind to isobars; the influence of different shapes of isobars in modifying the distribution of heat and cold from day to day in various parts of the world; squalls, thunderstorms, and non-isobaric rains; and pamperos, whirlwinds, and tornados, are all severally discussed.

The author then considers the local influence of the configuration of the earth's surface, and devotes a chapter to the diurnal phenomena of weather, with special reference to the manner in which they modify the weather that characterises each shape of isobars.

After referring to annual and secular variations, and to types and spells of weather, the author concludes by dealing with the question of forecasting. He shows what a solitary observer, with a barometer and his eye observations on clouds and prognostics, can do in the way of forecasting, and explains why the indications of the barometer sometimes appear to fail. He then shows what a meteorologist can do, seated in a central office, with telegraphic communication in all directions, and who, after making a synoptic chart, and combining it with every other modern aid, issues telegraphic forecasts to all parts of the country.

The book is very copiously illustrated with charts, &c. from various parts of the world.

RECENT PUBLICATIONS.

AMERICAN METEOROLOGICAL JOURNAL. A Monthly Review of Meteorology, Medical Climatology and Geography. Vol. IV. Nos. 6-8. October-December 1887. 8vo.

The principal articles are:—Some results derived from the hourly observations of atmospheric pressure at the Blue Hill Observatory during 1886, by A. L.

[1] *Weather. A popular Exposition of the Nature of Weather Changes from day to day.* By the Hon. Ralph Abercromby. International Scientific Series. 8vo. 1887. 472 pp.

Rotch (2 pp.).—Pressure and Temperature in High and Low, by Prof. H. A. Hazen (6 pp.).. [For a full abstract of this paper see p. 74.]—On the absolute Reduction of Wind Observations at Sea, by F. Waldo (6 pp.).—Meteorological Observations during the Solar Eclipse of August 19th, 1887, made at Chlamostino, Russia, by W. Upton and A. L. Rotch (13 pp.).—Is the Rainfall increasing on the Plains? by M. W. Harrington (4 pp.).

ANNALI DELL' UFFICIO CENTRALE METEOROLOGICO ITALIANO. Serie II. Vol. VI. Parte 1. 1884. 4to. 1886.

Among much other information this volume contains the following articles :—Osservazioni microscopiche sulle Polveri dell' aria, del Prof. P. Bonizzi (16 pp.).—Alcune notizie sull' Osservatorio Meteorico di S. Agata Feltria e descrizione di un Anemoscopio elettrico a resistenze variabili. Nota di Astasio Luchesi (12 pp.).—Anemoscopio ed Anemometro a transmissione elettrica dei Fratelli Brassart (7 pp.).—Osservazioni dei temporali raccolte nel 1882 e nel 1883, per cura der Dr. C. Ferrari (259 pp.).

ANNUAIRE DE LA SOCIÉTÉ MÉTÉOROLOGIQUE DE FRANCE. Tome. XXXV. June-August 1887. 4to.

Contains :—Marche annuelle de la radiation solaire sous le climat de Montpellier en 1883-1885, par F. Houdaille (5 pp.).—Résumé des observations météorologiques faites en 1878 et 1879 au poste de Boké (Rio-Nunez), par Dr. Bohéas (6 pp.).—Causes de la circulation atmosphérique, par M. Hauvel (6 pp.).—Observations hydrométriques de la Beauce, par Dr. Harreaux (5 pp.).—Sur l'enregistrement de l'intensité calorifique des relations solaires, par A. Crova (3 pp.).—Sur la transmissibilité de la radiation solaire par l'atmosphère terrestre, par A. Crova (5 pp.).

CHARTS OF THE BENGAL AND ADJACENT SEA NORTH OF THE EQUATOR. Published by the Meteorological Department of the Government of India.

The Indian Meteorological Department has issued two volumes of Charts of the Bay of Bengal, showing (1) the Mean Pressure Winds and Currents in each month of the year, and (2) the Specific Gravity, Temperature and Currents of the Sea Surface, the latter being represented by four seasonal charts. They embrace the area between the Asiatic Coast and the Equator, and 80°—100° East longitude. The results are based on observations recorded between the years 1855 and 1878. It should be noted that the Sea Temperatures given from the publications of the Meteorological Office refer to *individual months* and not to *seasons*. At all seasons the specific gravity of the equatorial sea to the South of the Bay is higher than that of the Bay itself; and from this area a limb of relatively high density is protruded northward into the centre of the Bay, where the density is least affected by drainage from the land. The density is lowest at the mouths of the Irawadi and the Ganges, but it varies considerably at different seasons of the year.

CIEL ET TERRE. Revue Populaire d'Astronomie, de Météorologie et de Physique du Globe. Deuxième Série. Vol. III. Nos. 15-20. 8vo. 1887.

The principal meteorological articles are :—De l'influence lunaire, par J. C. Houzeau (8 pp.).—L'irisation des nuages, par E. Lagrange (3 pp.).—La température superficielle des mers (8 pp.).—Coup d'œil historique sur les méthodes d'investigation et les lois de l'électricité atmosphérique, par Prof. Exner (18 pp.).

DAS WETTER. Meteorologische Monatsschrift für Gebildete aller Stände. Herausgegeben von DR. R. ASSMANN. Vol. IV. Parts 10-12. October to December 1887. 8vo.

Contains :—Ueber die Rolle der Elektricität bei meteorologischen Erscheinungen, von Dr. P. Andries (16 pp.).—Ueber Fallwinde, von Dr. H. Meyer (6 pp.).—Blitzgefahr, Baum-art und Boden-art, von Dr. Lehmann (8 pp.).—Das Aspirations-Psychrometer, ein neuer Apparat zur Ermittelung der wahren Temperatur und Feuchtigkeit der Luft, von Dr. R. Assmann (20 pp.).

INDIAN METEOROLOGICAL MEMOIRS: being Occasional Discussions and Compilations of Meteorological Data relating to India and the Neighbouring Countries. Published under the direction of H. F. BLANFORD, F.R.S. Vol. IV. Parts 2-3. 4to. 1887.

Contains:—The False Point Cyclone of September 22nd, 1885, by A. Pedler (80 pp. and 8 plates). This paper gives a full history of the meteorological conditions which attended the formation, progress and disappearance of the disastrous cyclone which visited Orissa in September 1885, and the centre of which struck False Point on the morning of the 22nd, causing a large destruction of life and property. The chief features of this cyclone were, first, the rapidity of its formation; second, its smallness; third, its fierceness; fourth, the extraordinarily low barometric pressure (27·135 ins.) registered during the storm, which is believed to be unprecedented; fifth, the destructive storm-wave accompanying it; sixth, the absence of any decided warning indications of the existence of so fierce a storm; seventh, the rapidity with which it abated in intensity after reaching the land; and lastly, the fact that while the cyclone was in process of formation the rainfall in Bengal was about equal to the normal for the time of year, the fact generally observed being that rain is almost withheld from the land during the formation of an intense cyclone. Generally speaking the history of this storm supports the "condensation" theory of the formation of cyclonic storms.—On the Ground Temperature Observations made at the Old Observatory, Allahabad, by S. A. Hill, B.Sc. (24 pp. and plate).

JOURNAL OF THE SCOTTISH METEOROLOGICAL SOCIETY. Third Series, No. IV. 8vo. 1887.

Among other information this contains articles on the following subjects:—Modern developments of Cloud Knowledge, by the Hon. R. Abercromby (15 pp.).—The Winds and Rainfall of Ben Nevis in 1886, by R. T. Omond (4 pp.).—On a peculiarity of the Cyclonic Winds of Ben Nevis, by R. T. Omond (2 pp.).—Contributions to Marine Meteorology resulting from the three years' work of the Scottish Marine Station, by H. R. Mill, D.Sc. (8 pp.).—Observations of Sea Temperature, made by the Staff of the Scottish Marine Station between 1884 and 1887 (64 pp.).—Temperature Observations on the Thurso, by J. Gunn (18 pp.).

METEOROLOGISCHE ZEITSCHRIFT. HERAUSGEGEBEN VON DER OESTERREICHISCHEN GESELLSCHAFT FÜR METEOROLOGIE UND DER DEUTSCHEN METEOROLOGISCHEN GESELLSCHAFT. Redigirt von Dr. J. HANN und Dr. W. KÖPPEN. October-December 1887. 4to.

Contains:—Ueber einige die Wolken-und Luftelectricität betreffende Probleme, von Dr. Linss (17 pp.). This is a criticism of various theories of the origin of atmospheric electricity, but the author comes to no definite conclusion.—Die Niederschlagsverhältnisse in der Bukowina, von Dr. A. Wachlowski (7 pp.).—Regen und Wald in Indien, von Dr. Brandis (8 pp.). This interesting paper shows what has already been done in the way of protecting the forests of India, and the immediate result in the way of increasing rain and improving agriculture.—Ueber simultane Beobachtungen, von Prof. Buys-Ballot (4 pp.). This is an appeal to meteorologists in general to carry out discussions of diurnal range, &c. for their own countries, in continuation of the tables which the Chief Signal Office proposes to publish on the cessation of its synchronous observations at the end of 1887.—Ueber eine neue Quellentheorie auf meteorologischer Basis, von Dr. O. Volger (10 pp.). The author maintains that springs are fed by ground water, and are not in any way dependent on rainfall. The water in the ground, according to him, is produced by some subterraneous condensation of the moisture of the atmosphere.—Ueber die jährliche Periode der Richtung des Windes in Mittel- und West-Europa, von Dr. F. Augustin (6 pp.). This is a discussion of the wind direction results, as to frequency, in West Europe, for 52 stations. In addition, detailed tables for each month are given for 8 stations. The general result is that the maximum of frequency changes in winter from East to West by South, and in summer from East to West by North.—Resultate der meteorologischen Beobachtungen der österr. Polar-Station auf Jan Mayen 1882-83, von Dr. J. Hann (6 pp.).—Zur Frage der Luftströmung, von W. Siemens (4 pp.).—Ueber die Häufigkeit des Vorkommens gegebener Tem-

peraturgruppen in Norddeutschland, von Dr. H. Meyer (14 pp.). This is an investigation into the number of times certain readings of the thermometer recur in North Germany. The results indicate *inter alia* the variability of temperature at the respective stations. The author gives expression to his own views as to the insufficiency of the mere arithmetical means to represent the true state of temperature, inasmuch as the number of observations is not infinite, and the observations themselves are not independent of each other. The editors of the *Zeitschrift* insert a note of caution as to these views of Dr. Meyer's.—Die Gewitter vom 13-17 Juli 1884 in Deutschland, nach Dr. R. Börnstein (12 pp. and plate).

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON. Vol. 178. A. 12. 4to. 1887.

Contains :—Some Anomalies in the Winds of Northern India, and their relation to the distribution of Barometric Pressure, by S. A. Hill, B.Sc. (44 pp. and 3 plates). From the evidence put forward in this paper the author thinks it will be generally admitted that the hot winds of Northern and Central India cannot be satisfactorily explained by the distribution of pressure at the earth's surface, and that Köppen's hypothesis of convective interchange between the upper and lower strata is probably the true explanation of them : (1) because the vertical distribution of temperature is such that convective action must take place ; (2) because the diurnal variation of the intensity of these winds and their characteristic dryness suggest such an origin for them ; and (3) because the distribution of pressure at 10,000 feet above sea-level in May is such as to produce winds of the observed direction. The distribution of the upper currents as suggested by the charts also elucidates many other obscure points in the wind system of India, and the same hypothesis of the origin of westerly winds gives a rational explanation of the law worked out by Mr. Blanford connecting the spring snowfall of the North-west Himalaya with the rainfall over the plains during the succeeding summer monsoon.

PROCEEDINGS OF THE ROYAL SOCIETY. Vol. XLIII. No. 258. 8vo. 1887.

Contains :—On the Relation between Tropical and Extra-tropical Cyclones, by the Hon. R. Abercromby (30 pp.). Every cyclone has a double symmetry. One set of phenomena, such as the oval shape, the general rotation of the wind, the cloud ring, rain area, and central blue space, are more or less related to a central point. Another set, such as temperature humidity, the general character of the clouds, certain shifts of wind and a particular line of squalls, are more or less related to the front and rear of the line of the trough of a cyclone. The author's researches show that the first set are strongly marked in the tropics, where the circulating energy of the air is great and the velocity of propagation small, while the second set are most prominent in extra-tropical cyclones where the rotational energy is moderate and the translational velocity great. The first set of characteristics may conveniently be classed together as the rotational, the second set as the translational phenomena of a cyclone. Tropical and extra-tropical cyclones are identical in general character, but differ in certain details due to latitude, surrounding pressure, and to the relative intensity of rotation or translation.

REPERTORIUM FÜR METEOROLOGIE. Herausgegeben von der Kaiserlichen Akademie der Wissenschaften. Redigirt von DR. HEINRICH WILD. Band X. 4to. 1887.

The principal papers are :—Ueber die persönlichen Fehler bei Schätzung des Bewölkungsgrades, von K. Laurenty (22 pp. and plate). This is an examination of cloud notations made by three experienced observers to the number of about 1,400 apiece. From this it comes out there is a strongly marked personal equation which appears at all seasons. The author remarks that the usual mode of estimation favours the appearance of personal errors because sufficient attention is not paid to the difference between zenithal and horizontal observations.—Neue Versuche über die Bestimmung der wahren Lufttemperatur, von Dr. H. Wild (32 pp.). The author replies to the criticisms of Dr. Assmann and Prof. Hazen. His general conclusions are :—1. The Russian Thermometer Screen, galvanised iron under a wooden shed, gives the true temperature within $\pm$ 0°·1 C. In very calm hot days in summer some ventilation is desirable, especially if it is wished

to make hygrometric observations in the screen. 2. On calm days with strong radiation the determination of temperature can vary to the extent of 0°·5 C, according to the nature of the shade in which the thermometer is situated and the height above ground (from 0·8 to 3·8 metres). A grass plot, which in sunshine may have a temperature 14° above that of the air at 3 metres above it, can fall to 5° below the air temperature when it comes into shade, and it may even occur, if the area of shadow is large enough, that the temperature may rise with height above the ground. 3. Thermometers with ordinary glass bulbs stand, as regards the influence of radiation, between those with smoked and those with gilt bulb. The gilt bulb sling thermometers are less affected by radiation than the glass. 4. Wooden screens always promote sluggishness in thermometers.—Die Gewitter Russlands im Jahr 1884, vom A. Schönrock (32 pp. and plate).—Die Bahnen der Anticyclonen in Europa, von P. Braunow (23 pp. and 16 charts). This is an investigation of the movement of anticyclones in Europe. The author finds that they move in general towards East-south-east. Their prevalent motion does not agree with that of the minima, but diverges from it as much as 67°·5 There is no great variation in the velocity of motion of the maxima throughout the year, and the annual range of velocity noticeable in minima does not exist. Maxima arise in two ways: 1st, from terrestrial radiation. These are said to be of thermal origin. 2nd, from the proximity to each other of two minima. These anticyclones are said to be of dynamical origin. As to the direction of motion, this takes place towards the region where the temperature falls most. If the temperature falls slightly and uniformly the anticyclone does not move.—Die Cyclonenbahnen in Russland für die Jahre 1881-1883, von B. Ssresnewsky (37 pp. and 12 charts). This is an investigation on similar lines to those of Leyst, Spindler and Braunow in former years. The author has investigated 195 cyclones in the course of three years. Their average motion was 19·3 miles per hour. The mean direction was N 69° E. The velocity and the azimuth of motion was greatest in winter and least in summer.—Weitere Untersuchungen über die Bestimmung der wahren Lufttemperatur, von Dr. H. Wild (24 pp.).—Jahresbericht des physikalischen Central-Observatoriums für 1885 und 1886 (142 pp.).—Vereinfachte hypsometrische Tabellen, von B. Ssresnewsky (16 pp.).—Witterungsbeobachtungen an der Ishma, angestellt von Diakonus Istomin, von R. Bergmann (26 pp.).

SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. Vol. XXII. Nos. 261-263. October to December 1887. 8vo.

Contains, among other information, the following articles:—The Thunderstorm of August 17th, 1887 (3 pp.).—The Climate of Tonquin (2 pp.).—Is Terrestrial Magnetism concerned in Atmospheric Movements? by M. A. Veeder (3 pp.).—A Bolide exploded over Central England (9 pp.).

WEATHER CHARTS AND STORM WARNINGS. By ROBERT H. SCOTT, M.A., F.R.S., Secretary to the Meteorological Council. With Numerous Illustrations. Third Edition, Revised and Enlarged. 8vo. 1887. 229 pp. and 8 plates.

This work is intended to afford an explanation of the Weather Charts which appear in the Newspapers, and of the remarks which accompany them. The entire text in this edition has been revised, and several new chapters have been added, viz. the Distribution and Periodicity of Gales, Weather Forecasting, the Weekly Weather Report, and Cirrus Cloud Observations.

QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY.

VOL. XIV. APRIL 1888. No. 66.

THE USE OF THE SPECTROSCOPE AS A HYGROMETER SIMPLIFIED AND EXPLAINED.

BY F. W. CORY, M.R.C.S., F.R.Met.Soc.

[Received September 28th—Read November 16th, 1887.]

MORE than four years have now elapsed since I had the honour of bringing before the Society a paper entitled "The Spectroscope as an aid to Forecasting Weather."[1] During this period the advocates of this instrument have increased, and it is gratifying to relate that many observers who have employed it in their meteorological researches have almost unanimously arrived at the conclusion that the spectroscope must now be indisputably considered a hygrometer of unparalleled value.

One cannot but concede, however, that there are difficulties in the way of its universal adoption, not only as part of the outfit of the individual observer, but even as one of the standard instruments of a recognised meteorological station.

[1] *Quarterly Journal*, Vol. IX. p. 234.

The first, and apparently the most important, difficulty to which I would refer, is that of correctly estimating the amount of the principal rainband. Some are loth to accept a mental scale, because the personal equation must necessarily vary with each observer, and results would not be comparable. Mechanical means have been successfully employed by Prof. C. S. Cook in America for measuring the intensity of the principal line of the rainband, and some startling results have been obtained with his ingenious instrument. Unfortunately the great cost of its production is a bar to its coming into more general use.

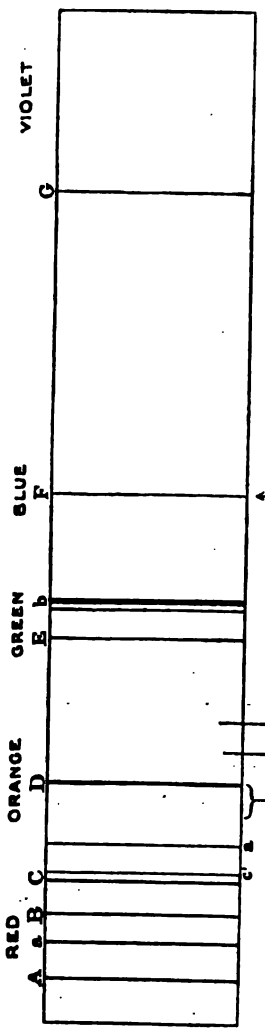
Advantage has been taken of the spectrum bands of Didymium, so that after having assigned a certain percentage value to each one, they may be placed by the side of the sky spectrum, and a calculation can then be made with a greater degree of confidence of the real percentage of rainband present.

Now, I have come to the conclusion, after a most careful consideration of the whole matter, that the application of mechanical means to the measurement of the rainband in its entirety, in spectroscopes of moderate dispersion, will be found next to impossible and thoroughly misleading. It is well known that this rainband to the red side of D presents to the eye of the observer most Protean characteristics, because it is ever varying in the intensity of its component lines, and in the depth of shade at different parts, and in the extent to which it approaches the least refrangible end of the spectrum. I believe that all these remarkable variations indicate alterations that are continually taking place in the invisible vapour of the atmosphere. Such changes, although at present inexplicable, are no doubt full of meaning, and would furnish us with invaluable assistance in predicting weather.

After all, it seems to me, we must still keep to a mental scale, and try to carefully educate our observers to the attainment of proficiency therein. If an easy range of from 0 to 5 be adopted, as suggested by Mr. Rand Capron, errors in estimating percentage would be considerably reduced. As to the trouble and time occupied in teaching the tyro how to use the instrument, a great deal more than five minutes' hurried conversation, with reference to a few diagrams, must be devoted to an instrument of such marvellous power.

Another impediment to some observers is that the rainband cannot be made to indicate every form of aqueous precipitation by an increase in intensity. Now, I have on several occasions pointed out and clearly proved that the rainband *diminishes* before snow, hail and very cold rain.

Therefore, one must not hastily arrive at the conclusion that this instrument is worthless, because a small amount of rainband is at times followed by heavy rain of low temperature. It is a well-known fact in meteorology that snow is frequently melted whilst passing through a warm substratum of air, and falls to the ground as cold rain. A few years ago I was caught in a slight snow storm at the top of Arthur's Seat, Edinburgh, and on arriving in the town below three or four people assured me that they had had nothing but rain in the same storm. From this circumstance you will at once see how readily a false assumption may creep in, and acknowledge how unreasonable it is to expect the spectroscope to show an increase of vapour lines before



This diagram shows the relative, but not the actual appearance of some of the lines and bands of the sky spectrum.

The parts marked 1, 2 and 3 are specially referred to in the paper: r shows the position of the principal rainband; δ the dry air or low sun band; V the rainband; and F the constant solar line.

In the case of the bands δ and V the lines are drawn as nearly as possible in the centre of the shading.

The approximate position of the colours is denoted at the upper part of the diagram.

hail, snow, or melted snow or hail coming down as rain. In another case this band becomes much darker, at the same time the temperature rises, no rain falls, and again the spectroscope is pronounced fallacious. This anomaly is easily explained, for it is another well-known fact in meteorology that air, when increasing in temperature, is capable of absorbing more moisture, and thus the vapour lines in the spectrum are naturally increased, and it depends on the temperature and electrical state of the atmosphere whether rain falls or not. Temperature *must* be considered in drawing deductions from this instrument, and not only temperature, but the state of the F line, and the δ and V bands. And yet it is astonishing what a large amount of success attends an observer who pins his faith on the rainband alone, and takes no

account of the other parts of the spectrum, nor the proper quarter towards which the instrument should be directed. These are points on which I have laid particular stress in my little pamphlet entitled *How to Foretell the Weather with the Pocket Spectroscope.*

Let me here interpolate a few aphorisms which, in my opinion, can be accepted beyond doubt.

1st. Given a large amount, say 80 per cent., of the principal rainband; an indistinctness of the F line, seemingly hidden away in the blue, which is deep and dark; an intensified darkness of the δ and V bands, the temperature of the external air being about 55°. This combination indicates with certainty the occurrence of a heavy fall of rain within twenty-four hours, either at the place where the observation was made or in the immediate neighbourhood.

2nd. With the same temperature of 55°, a moderate rainband, say 20 per cent., the F line being clear and distinct, and the V band not at all marked. Again, with certainty one can predict that during the next twenty-four hours fine weather will be experienced.

3rd. 50 per cent. of rainband has a greater value for rain in the winter than in the summer season of the year; or, in other words, rain is more likely to fall with a low temperature, and 50 per cent. rainband, than with this same percentage accompanied by a much higher temperature.

4th. An increasing rainband foreshows either higher temperature or rain. The appearance of the F line and the V band will decide which.

5th. A diminishing rainband will be followed by fine weather, lower temperature, snow or melted snow as cold rain. The F and V will again settle the question.

6th. Clearness and good definition of the F line are indicative of fine or windy weather, whilst rain, snow or hail may be expected with the opposite condition of the line.

7th. Rain is generally preceded by intensified darkness of the δ and V bands. V is a rainband *per se*, and before heavy falls of rain is for the most part joined to δ in one dark band.

8th. The observer must take care not to depend too much on the increased darkness of the δ and V bands at the time of low sun, as this is their natural condition at that particular period of the day.

It will be noticed that I have only mentioned three parts of the spectrum to whose changes the observer ought to pay especial attention. There are other bands and lines of great importance, but I shall not advert to them in this paper, as my present object is to suggest as simple a way as possible of using the spectroscope as a hygrometer, in order to facilitate its introduction amongst observers as a standard meteorological instrument. The best form of hygro-spectroscope, as a recognised standard for the purpose of investigating and scrutinising the changes of the above mentioned parts of the spectrum, is that originally termed by Mr. Rand Capron "The Rainband Spectroscope." It ought to have a fixed slit, and in addition a milled wheel at the side for the easier adjustment of the focus.

A larger kind, called "Grace's," is preferable for the examination of the

whole spectrum, but the former will be found more portable, less expensive, and, I really think, more suitable for estimating the amount of rainband. At the request of Prof. Ragona, of Modena, I have had a set of Hints to Observers printed for ready reference. He has kindly offered to circulate them amongst scientific men in Italy. They are as follows :—

1.—For taking weather observations with a pocket spectroscope, one of moderate dispersion will be found the most suitable.
2.—When using the instrument, exclude as much as possible all extraneous light from the eyes.
3.—Be careful to adjust the slit and the focus, so that the lines of the spectrum may be of the clearest definition.
4.—An adjustable slit is not a *sine quâ non*, for those instruments that are fitted with it seldom require altering when once it has been correctly positioned. Many of them are sold with a fixed slit, which is sufficient for all practical purposes.
5.—When dark lines cross the colours parallel to the length of the spectrum, it is an indication that dust is in the slit. To get rid of it do not use a cloth, a piece of paper, or a camel-hair brush, but cut the end of a match into a wedge shape, and pass this to and fro between the jaws of the slit.
6.—If the breath condenses on the eye-piece, move the instrument up and down until the glass is clear. A good plan is to slightly heat this end in front of the fire, or by exposure to sunshine, or even by applying it to the warm and dry skin just before taking an observation.
7.—The best regular times for systematically using this instrument are at 9 a.m. and at 3 p.m. all the year round. The clearer the atmosphere, and the quieter the meteorological conditions then prevailing, the less frequently it will be necessary to use the spectroscope for the purpose of forecasting rain, and *vice versâ*.
8.—Examine the sky spectrum at four points of the compass and at the zenith, in the former at an angle of about 13°. Especially observe towards that quarter from which the wind is blowing, or from which it is likely to come; for deductions in regard to future weather from the general appearance of the spectrum in that direction will prove far more successful than if this system be not adopted.
9.—If the last rule be impracticable, observe in a northerly in preference to a southerly direction, or, at all events, with the back to the sun.
10.—If possible, look towards blue sky, and carefully avoid reflected sunlight as much as you can.

In conclusion, I would suggest that the Council of this Society should take some steps to make the Fellows better acquainted with the spectroscope as a hygrometer. It seems to me, and I feel very strongly on the point, that from a retrospect of most that has been done within the last few years, it is desirable that we should extend our investigations into the upper regions of the atmosphere, of which we know so little.

DISCUSSION.

Mr. DYASON said that the author deserved thanks for his attempt to discover reliable spectroscopic factors as elements in the forecasting of weather. If he understood the paper rightly, it gave Mr. Cory's results, obtained by five years continuous labour. There appears to be a haziness and uncertainty, from no fault of the author, all through the paper. He took it that the author had made this subject a special study, and had brought all the information he could get to bear upon the subject. He (Mr. Dyason) would not venture to say so much, had he not been also, although feebly, working at the same subject. The problem is, can bands, notably the rain band to the left of D, of the spectrum, be observed a

differentiated and recorded so as to be used as factors in meteorology. He had made for some years with a Pocket Spectroscope observations now and again whenever practicable—on the Alps 12,000 feet, at sea level, on the Scotch Moors, on Ben Nevis, on the Surrey Downs, in the valleys, near the Metropolis 400 feet, through a cylinder of aqueous vapour, in the tropical house at Kew, through condensed aqueous vapour on glass; and speaking generally, without satisfactory results. He had found that when the observations were taken nearly in the direction of the bright sun, whatever the humidity of the atmosphere, there was no rainband near the D line, but it could always be found more or less marked as he approached the horizon, the point of the compass being immaterial. We are too much accustomed to look upon the atmosphere as monochromatic rather than polychromatic, the spectroscope is teaching us much in the latter direction. When there is sufficient light to observe the spectrum, there is also sufficient light for the naked eye to observe *other* chromatic effects.

Dr. BLACK said that he had used the Pocket Spectroscope in several places, but without good results. The rainband has been visible, but not sufficiently marked in order to give a forecast. It is most prominent at the sea-coast, whilst at inland places the rainband is often quite absent, and yet rain has followed soon after at those places. The direction of wind has the most effect upon the bands. The Pocket Spectroscope should be larger, as the small instrument was of no value.

Mr. WILSON inquired what was the rainband? Was it a band in the spectrum indicating falling rain or a certain degree of humidity, or a certain amount of water vapour in that section of the air to which the Spectroscope is directed? Would it indicate combined nitrogen or other dissolved or suspended matter? Apologising for the irrelevancy, he took the opportunity of asking if other Fellows of the Society agreed with him in thinking that a large amount of moisture, probably containing a proportion above the average of dissolved salts (notably nitrates), is frequently condensed upon growing plants when no indication of atmospheric precipitation is indicated by the rain-gauge. This is particularly evident with trees in cold foggy weather. In a thaw, after trees have been covered with hoar frost or silver thaw, a rain-gauge set under a tree would collect a good deal of water, whilst a gauge in the open would collect none, or possibly if very large, a very little dew.

Mr. SYMONS said that he did not understand how the Spectroscope showed whether rain or snow would be likely to fall. In reply to a remark from Mr. Wilson, he stated that the question of horizontal and vertical rainfall had been fully discussed, the basis being fifteen years' observations taken at Rotherham by Mr. Chrimes, the results of which were printed in the *British Rainfall*. It was found to be simply a question of the force of wind blowing with the rain. Large drops on account of their weight do not fall at such an angle as small ones.

Mr. A. LAWRENCE ROTCH said that he had used the Spectroscope, but had not been very successful in foretelling rain by it. The average success of predictions made at the Blue Hill Observatory, Mass., U.S.A., for eight hours in advance, from the Spectroscope alone, for the warm months of July, August, and September, was 85 per cent. for the morning, and 80 per cent. for the afternoon observation; for the cool months of October and November, 81 per cent. for the morning and 87 per cent. for the afternoon observation; and for the cold months of December, January, February, and March, 75 per cent. for the morning and 81 per cent. for the afternoon observation. A higher degree of success in rain predictions for eight hours in advance could probably be attained by simple observations of the wind and clouds.

Mr. ABERCROMBY said that the author had proved himself to be a most accurate and skilful observer, both in this and a paper which he had previously contributed to the Society, and had made several distinct advances in meteorological spectroscopy. Mr. Cory's discovery of the diminution of the rainband before snow and cold rain, and the attention which he had directed to the significance of the V band, were all worthy of much notice. At the same time he (Mr. Abercromby) had not found the Spectroscope give such good results in his own as in Mr. Cory's hands; and he was quite certain that the whole future of rain forecasting did not depend on hygrometry in any form. At the same time the Spectroscope sometimes gave information that no other instrument did. He should like to ask the author his opinion as to the origin of the V band, for he (Mr. Abercromby) had

only seen it when looking through thick masses of cloud, except when the sun was very low. If the V band was caused by cloud, the value of the spectroscopic evidence was diminished, for the eyes could see the rain coming on. This would also show that the V band was due to the absorption of water dust and not to that of vapour. He would also like to ask if the author had given any attention to the significance of the *alpha* and *c'* lines, as there was some reason to believe that part of the *alpha* line at all events was due to water and not to vapour. In conclusion, he hoped that so careful an observer as the author would turn his attention to the difference between water and vapour lines generally.

Mr. SCOTT said that he did not consider that Mr. Cory had made much more progress in defining the percentage of the Spectroscope than was shown in his paper four years ago. He inquired what was meant by the phrase 80 per cent. of rainband. What was 100 per cent., and what was the standard? The Meteorological Council had had the subject under their consideration, but they had never been able to find a standard to which they could refer. He then referred to Prof. Cook's instrument, and said that Prof. Winslow Upton had alluded to it, and remarked that such an instrument, the cost of which was about £50, could only be used at first-class observatories.

Mr. C. HARDING said that it was very expedient that there should be some rules for the use of the Spectroscope. It was desirable to agree with other authorities as far as possible. At present the instructions for observing were very conflicting; Prof. Piazzi Smith recommended one method, Mr. Cory another, and the United States Signal Service and others something quite different. Prof. Winslow Upton, in his pamphlet "On the Use of the Spectroscope," details the following system of observation in the United States:—"1. The Spectroscope is directed to the sky near the horizon, and the intensity of the band estimated upon a scale of 5. 2. The Spectroscope is then directed to the sky at an altitude of 45°, and similar estimate is made. 3. The sum of the two readings is taken for the value of the observation, which is therefore upon a scale having 10 for its maximum." He (Mr. Harding) thought that Mr. Cory intended 100 per cent. to mean the greatest intensity which the rainband could show. Prof. Upton remarks: "The formation of the mental scale of comparison should receive careful attention. The maximum intensity must be determined by experiment. It may often be obtained from the western sky at sunset, or still better by examining the sky just before a heavy rain storm, or while rain is falling. Some observers adopt the scale 0 to 10, but it will be found that the scale 0 to 5 presents as many gradations as can well be estimated." Prof. Upton also remarks that "the observation is also partially or wholly a failure, as far as forecasting rain is concerned, when the sky is covered with clouds;" a very serious objection to the value of the instrument if this limitation equally holds in our own country.

Mr. CORY, in reply, said that the rainband was a manifestation of invisible vapour lines, and ought not to be used alone in forecasting. When the clouds were heavy, any increased darkness of the V band was most probably due to absorption of light, the darkness depending on the thickness and density of the clouds as well as the amount of invisible vapour. The following figures showed the percentage of cases of rain and snow met with after 25 per cent. of rainband, that is, without taking into account temperature, or the features of any other part of the spectrum, all of which were so necessary for successfully forecasting rain or snow:—

In 1884,	21·4	per cent. of rain	and	7·1	per cent. of snow.
„ 1885,	36·1	„	„	6·1	„ „
„ 1886,	29·4	„	„	—	„ „
„ 1887,	15·7	„	„	10·5	„ „

The percentage of successes in Mr. Rotch's experience was very high, considering the rainband alone was used. Greater success would be obtained by noting the temperature, and by using the F line and the δ and V bands. The Spectroscope gave results where other instruments fail. The scale was a mental one, as recommended in his paper four years ago. The δ was a dry air and low sun band, and simply showed the absorption of light. The spectrum varied very much when the sky is clouded. He had many times successfully forecasted fine weather when thick and heavy clouds were about.

The only reason why he made use of the term percentage in estimating amount of rainband was, that when he first took observations he thought it would be best

to adopt such a system, so that in course of time if any finer divisions were made out either by the help of instruments or otherwise, other numbers could easily be interpolated, and so would not interfere with the scale one had become accustomed to.

THE NON-INSTRUMENTAL METEOROLOGY OF ENGLAND AND WALES.

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The Royal Meteorological Society in 1878 commenced the publication in their *Quarterly Journal* of the observations made at their Stations, both Instrumental and Non-Instrumental, subsequently embodying them in a separate publication entitled the *Meteorological Record*.

A number of the observations were printed with the international symbols; others, *e.g.* rain and snow, were given both in type and symbols. As the symbolic printing was discontinued at the end of 1885, the observations now discussed are only for the 8 years, 1878-1885 inclusive.

With the view of simplifying matters the Stations were divided into groups or districts in accordance with the Meteorological Office system (see accompanying map). These are as follows, and in discussions are designated by Roman figures.

0. Scotland, N.	VI. Scotland, W.
I. Scotland, E.	VII. England, N.W. (and N. Wales).
II. England, N.E.	VIII. England, S.W. (and S. Wales).
III. England, E.	IX. Ireland, N.
IV. Midland Counties.	X. Ireland, S.

V. England, S. (London & Channel).

The first two districts, 0. Scotland, N. and I. Scotland, E., are without representatives in the list of observers of the Royal Meteorological Society. District VI. Scotland, W. is represented by one station only, Scaleby in the north of Cumberland. District IX. Ireland, N. had one station only for 2 of the 8 years discussed in the paper. District VII. England, N.W. had but one observer (Llandudno) also for 6 of the 8 years discussed for that district.

It is noticeable in examining the weather tables that considerable inequality exists among the observers in the degree of fulness with which they enter their observations. In several cases the phenomena represented by symbols are rarely or very sparsely noted, in others the entries are very frequent.

From the causes above named the observations treated have not been considered sufficient to afford very reliable results, and hence those for districts VI., IX. and X. have been entirely omitted, and for the remainder it has not been the practice to carry the means out to decimals, but in all cases the nearest unit figure has been recorded. This is the reason why in so many instances no entries are found of the occurrence of certain of the less frequent atmospheric phenomena.

Map showing the Districts.

Table I. gives the average number of days on which the different kinds of weather took place in each district in the four different quarters of the year expressed as the number of days per month.

The Spring quarter comprises March, April and May.
„ Summer „ „ June, July and August.
„ Autumn „ „ September, October and November.
„ Winter „ „ December, January and February.

The total number of days per annum is also computed.

TABLE I.—Atmospheric Phenomena, Seasonal Values, Mean Monthly Occurrence.

Districts.	Number of Days of																				
						Wind.															
	Rain.	Snow.	Clear.	Overcast.	Gales.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Hail.	Fog.	Thunderstorm.	Thunder.	Lightning.	Solar Halo.	Lunar Halo.	Aurora.
Spring:—																						
II.	14	3	3	9	1	3	4	3	3	3	5	4	3	2	2	3	1	1	0	0	0	0
III.	14	2	4	11	1	2	6	4	3	3	6	4	4	1	2	2	1	1	0	0	0	0
IV.	14	2	3	10	1	3	3	5	3	3	4	5	4	2	1	1	1	1	0	0	0	0
V.	12	2	5	10	1	3	5	4	1	2	5	4	3	4	1	4	0	0	0	1	1	0
VII.	13	3	5	8	1	3	3	6	3	3	4	7	3	1	1	2	0	0	0	0	0	0
VIII.	15	2	5	11	2	3	4	4	2	2	6	4	3	3	1	3	0	0	0	0	1	0
Means	14	2	4	10	1	3	4	4	3	3	5	5	3	2	1	3	1	1	0	0	0	0
Summer:—																						
II.	16	0	1	10	1	3	3	2	3	3	7	5	3	3	0	3	2	2	0	0	0	0
III.	14	0	3	12	0	2	4	2	3	2	7	5	4	1	1	1	2	2	1	0	0	0
IV.	17	0	2	10	1	2	2	3	2	3	5	6	5	3	0	1	2	2	0	0	0	0
V.	15	0	3	10	1	2	3	2	1	3	7	6	3	5	0	3	1	1	1	1	0	0
VII.	14	0	3	13	1	3	1	3	1	3	4	10	4	1	0	1	1	1	0	0	0	0
VIII.	17	0	2	11	1	2	2	2	1	3	7	6	3	3	0	3	1	1	1	1	0	0
Means	16	0	2	11	1	2	3	2	2	3	6	6	4	3	0	2	2	2	1	0	0	0
Autumn:—																						
II.	18	2	3	10	1	3	3	2	2	3	6	5	5	3	1	4	0	0	0	0	0	0
III.	16	2	3	12	1	2	3	3	3	2	6	6	5	1	1	3	0	0	1	0	0	0
IV.	17	1	2	11	1	3	2	3	2	3	5	6	4	3	1	3	1	0	0	0	0	0
V.	15	1	4	11	1	3	3	2	1	2	5	5	3	5	0	7	0	0	0	1	1	0
VII.	17	1	3	13	2	3	2	3	2	3	4	10	2	1	2	2	0	0	0	0	0	0
VIII.	18	1	3	12	3	3	4	3	1	2	6	5	3	4	1	4	0	0	1	1	1	0
Means	17	1	3	11	2	3	3	3	2	3	5	6	4	3	1	4	0	0	0	0	0	0
Winter:—																						
II.	16	6	3	11	2	2	1	1	3	4	7	6	4	2	1	6	0	0	0	0	1	0
III.	16	5	3	16	1	1	2	2	4	3	8	5	4	1	1	5	0	0	0	0	1	0
IV.	15	5	2	13	1	2	2	3	3	3	5	6	4	3	1	6	0	0	0	0	0	0
V.	15	3	3	16	1	2	3	3	2	3	6	5	3	5	1	8	0	0	0	0	1	0
VII.	15	3	3	13	3	2	2	3	3	3	5	9	2	1	1	3	0	0	0	0	0	0
VIII.	17	3	3	16	4	2	3	4	2	2	7	4	2	4	2	5	0	0	0	1	1	0
Means	16	4	3	14	2	2	2	3	3	3	6	6	3	3	1	6	0	0	0	0	0	0
Totals for the Year:—																						
II.	193	31	31	121	14	33	34	23	31	35	75	60	45	27	14	48	8	8	2	1	4	1
III.	179	23	38	155	11	21	45	30	36	28	80	60	53	14	12	33	9	8	4	1	4	0
IV.	191	25	26	128	13	30	25	37	31	35	58	69	47	35	5	32	5	4	2	0	2	0
V.	170	17	44	141	11	28	39	32	18	31	70	90	33	56	7	62	6	4	4	6	6	0
VII.	178	17	43	141	21	34	23	43	28	36	52	109	31	11	11	21	4	3	2	0	0	0
VIII.	198	15	37	149	28	30	40	41	19	26	77	55	35	39	12	48	6	3	5	11	5	0
Means	185	21	36	139	16	29	34	34	27	32	69	69	41	30	10	41	6	5	3	3	4	0

Rain.—We will first consider the element of precipitation. Under the heading of rain the number of days upon which rain fell is entered. The yearly average number of such days for the whole country discussed is 185, showing that approximately rain takes place in England every alternate day.

As may be expected the average is exceeded in the South-west, where there are 198 days recorded. Next comes district II. N.E. and IV. Midland Counties with 193 and 191 days. The driest district is V. S., 170 days, followed by VII. N.W., with 178 days, and then III. E., with 179.

The seasonal distribution shows that the mean monthly number of wet days does not vary very greatly, being 14 days in the Spring, 16 in Summer, 17 in Autumn, and 16 in Winter; but this is modified if we include snow, and then the total precipitation frequency becomes 16 days per month in the Spring, 16 in Summer, 18 in Autumn, and 20 in Winter.

The distribution of rainy days is practically the same all the year round, VIII. S.W. being always the most rainy district, while V. S. is the one having the minimum fall.

Snow is most frequent in districts II. N.E. and IV. Midland Counties, which have averages of 31 and 25 days respectively; the fewest falls are in VIII. S.W., where they number 15. The mean monthly number of snow-falls is 2 in Spring, 0 in Summer, 1 in Autumn, and 4 in Winter, II. N.E. and III. E. showing in every case the greatest frequency.

Aspect of Sky.—We have only two classes here to treat—days with *clear* sky, and days when it was *overcast*; the latter in this country outnumbering the former in the proportion of 4 to 1, the means being for the year 139 overcast and 86 clear.

V. S. and VII. N.W. with 44 and 43 clear days respectively are the brightest districts, whilst IV. Midland Counties has but 26 clear days in the year. The most overcast districts are III. E. and VIII. S.W. with 155 and 149 cloudy days; II. N.E. and IV. Midland Counties stand lowest with 121 and 128 days per annum.

The mean monthly number of clear days is 2 in the Summer, 3 in Autumn and Winter, and 4 in the Spring; that of overcast days being 10 in Spring, 11 in Autumn and Summer, and 14 in Winter.

In Summer V. S. has the best sky with 8 clear and 10 overcast days, whilst II. N.E. has but 1 clear day per month. In Autumn V. S. is still good with 4 clear and 11 overcast days; VII. N.W. being the most unfavourable district, having 3 clear and 13 cloudy days. In Spring the distribution is pretty uniform, but VII. N.W. is the best with 5 clear and 8 cloudy, whilst IV. Midland Counties is the most unfavourable with 3 clear and 10 cloudy days in the month.

Wind Force.—The Weather Tables give only the two extremes—Gales and Calms.

The mean annual values for each division are 16 gales and 30 calms, but the local peculiarities of the Stations indicate considerable variation in the different districts, *e.g.* III. E. and V. S. having 11 gales, whilst VIII. S.W. shows 28 gales in the same time.

The mean monthly values are 2 gales in Winter and Autumn, and 1 each in the other two seasons. The highest frequencies observed are in district VIII. S.W., 4 in Winter and 3 in Autumn; the lowest II. N.E., III. E., and VI. Midland Counties 1 only in Winter.

Table II. has been prepared with the view of verifying the conclusions of Messrs. Scott and Prince as to the non-existence of equinoctial gales in this country. Contrasting the relative number of gales in the various months of the year, it will be seen at once that the total number of gales (100) recorded at all stations, when distributed throughout the year, forms a regular series having a maximum of 18 in October and November, and a minimum of 1 in June, the seasonal values being 34 in the Winter, 23 and 32 in Spring and Autumn respectively, and 11 in the Summer.

TABLE II.—GALES, MEAN MONTHLY NUMBER.

District.	II.	III.	IV.	V.	VII.	VIII.	Totals.	Season.
January	2	2	1	1	2	4	12	Winter
February	2	0	1	1	3	4	11	34
March	2	1	2	1	2	2	10	Spring
April	1	1	1	1	1	2	7	23
May	0	1	1	1	1	2	6	
June	0	0	0	0	0	1	1	Summer
July	0	0	0	1	0	1	2	11
August	1	1	1	1	2	2	8	
September	1	1	1	1	1	1	6	Autumn
October	2	2	2	1	3	3	13	32
November	1	2	2	1	3	4	13	
December	2	2	1	1	2	3	11	..
Totals	14	13	13	11	20	29	100	..

Calms.—Calms recorded do not exhibit a similar periodicity to the gales, or even an inverse one, as might be expected, for the maximum numbers notified in the country are 20 in December and 19 in September, and the minimum, 12 in April and May, and 18 in March. (Table III.)

TABLE III.—CALMS, MEAN MONTHLY NUMBER.

District.	II.	III.	IV.	V.	VII.	VIII.	Totals.	Season.
January	2	2	4	5	1	4	18	Winter
February	2	1	3	4	1	3	14	52
March	2	1	2	4	1	3	13	Spring
April	2	1	2	3	1	3	12	37
May	2	1	2	4	1	2	12	
June	3	1	3	4	1	3	15	Summer
July	3	1	2	5	1	3	15	46
August	3	1	3	5	1	3	16	
September	3	2	4	6	0	4	19	Autumn
October	2	2	3	5	1	3	16	50
November	2	1	3	5	1	3	15	
December	2	1	4	6	2	5	20	..
Totals	28	15	35	56	12	39	185	..

The mean annual number of calms per district is 80, distributed pretty fairly throughout the year, as 8 per month. The year the most frequent in IV. S. with 56 per annum, the fewest are VII. N.W. with 11 and III. E. with 14.

Wind Direction.—The winds having the greatest prevalence in this country are, as is well known, the West and South-west, both of which on the average blow 69 days in the year. The least dominant winds are the South-east and the North, which are credited with 27 and 29 days respectively.

Of the local distribution of the various winds we find the North wind is most frequent in VII. N.W. and II. N.E., with an annual mean of 34 and 33 days respectively. It is most rare in III. E., for which the value is but 21 days.

The North-east wind is most prevalent in III. E. (45 days) and VIII. S.W. (40), least in VII. N.W. (23 days) and V. S. (32 days). The East wind blows oftenest in VII. N.W., 43 times per annum, and VIII. S.W. 41, most seldom in II. N.E., 23 times.

South-east winds predominate 36 days in III. E. and 31 in II. N.E. and IV. Midland Counties, but only 18 days in V. S., and 19 in VIII. S.W.

The South wind is registered on 36 days yearly in VII. N.W., and 35 in II. N.E. and IV. Midland Counties, whilst on 26 days only in VIII. S.W.

The most common wind, the South-west, blows on the average 80 times in III. E., and 77 in VIII. S.W.; VII. N.W. and IV. Midland Counties are least favoured with this wind, having respectively but 52 and 58 days.

The West wind has most constancy in the VII. N.W. district, blowing there on an average 109 days in the year; IV. Midland Counties follows with 69 days, whilst VIII. S.W. has but 55.

In the case of the North-west wind the maximum frequency is in III. E. with 53 days, and IV. Midland Counties with 47. In VII. N.W. it only blows 31 days, and in V. S. 33 days per annum.

Of the seasonal distribution we find, as a rule, in Spring 5 days per month of South-west wind, in Summer 6 days of South-west and West to 2 of South-east and North. In Autumn also 6 of West with 2 South-east and 3 of each of the other directions, whilst in Winter there are 6 of South-west and West to 2 or 3 of each of the other points in the month.

Details of the distributions of winds are given in Table I.

Hailstorms, characterised by the symbol ▲, are next considered. On the average 10 of these occur every year; the district having the greatest number is II. N.E., with a mean of 14, whilst the least is 5 in IV. Midland Counties. The districts with next highest numbers are II. N.E., III. E. and VII. N.W., credited respectively with 14 and 12.

Of distribution according to season, we find in Spring a general average of 1 per month rising to 2 in the North, whilst in Summer the average over the whole country is less than 1 per month except in III. E., where it attains that figure. In Autumn the average is just over 1, rising to 2 in VII. N.W. only. The general average in Winter is also 1 except in VIII. S.W., where it rises to 2.

Fog.—As might be expected the greatest number of fogs are registered in V. S., which district comprises London and the Channel, the mean annual number being 62. Both II. N.E. and VIII. S.W. stand next with 48. Fogs are least frequent in VII. N.W., where the average is but 21.

In V. S. the mean monthly number of fogs is 4 in Spring, 8 in Summer, 7 in Autumn, and 8 in Winter. District IV. Midland Counties, on the other hand, has 1 fog in Spring and Summer per month per station.

Thunderstorms.—This class of phenomena is not very frequent in this country, the mean annual number being only 6 per station. Of the different districts, thunderstorms are most numerous in III. E. and II. N.E., where 9 and 8 are respectively noted; they are in the minority in VII. N.W., where they number but 4.

In Summer the average monthly number of storms is 2 in each of the districts II. N.E., III. E. and IV. Midland Counties, 1 in V. S., VII. N.W. and VIII. S.W. In Spring 1 is the mean for the first 8 districts only. In Autumn 1 only is also noted in district IV. Midland Counties; and in Winter the mean value for the whole quarter is but 0·4.

Thunder and Lightning are very similar in frequency and distribution to the last mentioned phenomenon, being embodied in it. The mean numbers observed per district per annum are 5 and 8 respectively. In Spring thunder is noted oncemonthly in districts II. N.E., III. E. and IV. Midland Counties, and in Summer twice monthly in the same districts. In the remainder of the year a few isolated observations only are entered, from which no mean values can be deduced.

Table IV. is the summary of all the observations of Electrical Phenomena,—thunderstorms, distant thunder and lightning—exhibited as yearly totals, those years in which twelve complete months' observations were not made being left blank.

Selecting individual Stations, the highest total number of thunderstorms, including under the term (K T and ≤), recorded at any places during the period 1878-1885 inclusive, were 218 at Hillington in III. E., being an average of 27 per annum, and 192 at Cheadle in IV. Midland Counties, with a mean of 24. The maximum number in any one year at any single Station was 40 in 1880 at Hillington, at which place was recorded also 34 in 1878. Cheadle registered 38 in 1882 and 33 in 1880.

Of the Stations where observations were carried on throughout the whole 8 years, Llandudno (VII. N.W.) has the lowest number, 74, or 9 per annum, Marlborough (V. S.) standing next with 98 or 12 per annum.

Entries of the remaining phenomena, Solar and Lunar Halos and Aurorae, are so infrequent, that nothing more can be discussed than the mean annual values. Solar and Lunar Halos are observed on the average 3 times in the year, but they vary considerably in their distribution, 11 being noted in VIII. S.W., 6 in V. S., and 0 in IV. Midland Counties and VII. N.W.

In conclusion the author regrets the incomplete form in which he has been compelled to put forward this paper: his desire being to utilise the observations published by the Royal Meteorological Society, he has not ventured to supplement them by reference to other sources of information, and hence his deductions are based on a somewhat scanty store of facts, and may therefore prove fallacious on further investigation.

TABLE IV.—Aggregate and Mean Number of Thunderstorms and Appearances of Thunder and Lightning observed at the Stations of the Royal Meteorological Society, 1878–1885 (Complete Years only being selected).

Stations.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	Sums.	Annual Mean.	District.
Wakefield	17	12	12	4	15	13	10	9	92	11·5	IV.
Buxton	19	17	23	18	18	14	23	15	147	18·4	IV.
Dartmoor	8	8	9	6	..	..	..	..	31	8	VIII.
Babbacombe .	23	12	28	18	11	22	25	14	153	19	VIII.
Norwood	26	15	30	9	11	19	14	13	137	17	V.
Hillington ..	34	29	40	17	28	24	25	16	213	27	III.
Strathfield T.	30	14	20	12	14	10	..	..	100	17	V.
Mansfield	22	14	26	11	..	..	..	..	73	18	IV.
Cheadle	22	21	33	22	38	16	24	16	192	24	IV.
Llandudno ..	8	13	15	8	12	8	7	3	74	9	VII.
Cheltenham ..	..	16	19	18	16	18	16	7	110	16	IV.
Carmarthen ..	19	11	13	4	9	9	16	7	88	11	VIII.
Ramsgate ..	20	6	5	6	..	..	..	..	37	9	V.
Audley End ..	27	21		..	..	..	..	..	48	24	III.
Lowestoft ...	..	10	18	7	14	11	16	9	85	12	III.
Kelstern	29	19	30	..	..	..	..	..	78	26	II.
Hereford	11	..	..	..	..	..	..	..	11	11	IV.
Shrewsbury ..	23	12	15	6	13	7	..	..	76	13	IV.
Churchstoke ..	19	16	15	13	25	15	11	10	124	16	IV.
Downside	..	15	19	14	13	13	..	..	74	15	VIII.
Marlborough..	21	6	16	7	17	15	11	5	98	12	V.
Scaleby	..	10	5	8	5	8	21	5	62	9	VI.
Southbourne..	..	..	6	6	6	4	11	5	38	6	V.
Croydon.....	..	15	31	13	19	15	27	..	120	20	V.
Scarborough ..	..	..	23	11	23	12	21	11	101	17	II.
Alnwick	..	..	..	11	13	15	..	..	39	13	II.
Killarney	..	..	..	..	9	9	15	3	36	9	X.
Cramlington ..	..	..	..	..	26	21	21	10	78	20	II.
Dublin	..	..	..	..	21	14	16	13	64	16	X.
Margate.....	..	..	..	..	..	13	22	12	47	16	V.
Rounton	..	..	..	..	..	18	25	15	58	19	II.
Londonderry..	..	..	..	..	..	..	5	2	7	4	IX.
Harestock	..	..	..	..	..	..	..	4	4	4	V.
Newton Reigny	..	..	..	..	..	..	..	8	8	8	VII.
Bennington ..	..	..	..	..	..	..	..	25	25	25	III.

Note added April 1888.

Since the reading of the paper, with the approval of the Editing Committee, it has been re-cast, all the observations from Stations in the districts VI. Scotland W., IX. Ireland N., and X. Ireland S. struck out, and the Tables re-computed.—G. M. W.

DISCUSSION.

Mr. Latham called attention to the large number of rainy days in the east of England, and thought that perhaps the apparent irregularities in the number of rainy days was due to the observers not always examining their gauges every day. Mr. Eaton had worked out the distribution of rainfall for the Croydon district, and found that both the quantity of rain and the number of rainy days increased with the height above sea-level. The apparent difference might be due to a gauge of very high elevation having been taken on the East Coast, while one of low

elevation was taken on the West Coast. The author of the paper no doubt had been at very great trouble in collating the observations, but it was extremely doubtful if the results were of any very great value.

Mr. MARRIOTT said that he was very glad that some one had begun to discuss the observations published in the *Meteorological Record*. He had hoped to have done so himself, but the time of the staff in the office was so completely taken up with the examination and reduction of the observations, and the preparation of the same for printing, that he was at present unable to do anything in that way. He thought that the paper would have been more interesting if Mr. Whipple had given a little more detail, and also explained how the observations were made. The observations at the Second Order Stations are made twice daily, viz. at 9 a.m. and 9 p.m. The rainfall is measured at 9 a.m., and the amount entered to the previous day. A fall of 0·006 in. and above constitutes a day of rain. When any snow falls, this is entered as a day of snow. When the mean of the 9 a.m. and 9 p.m. observations of the amount of cloud is less than 2·0, this is called a day of clear sky, and when the mean is above 8·0 it is called an overcast day. When the force of the wind is 7 and above (Beaufort scale), this is counted as a gale. The sums of the observations of the direction of the wind and calms at 9 a.m. and 9 p.m. are given in the tables in the *Record*. He (Mr. Marriott) thought that the peculiarities of the observers, and also their occupation—whether indoor or outdoor—might perhaps largely account for the reported appearance or otherwise of the various phenomena. He did not approve of Mr. Whipple's plan of grouping the stations into districts and then striking the average of the stations for that district. He thought that the best plan would have been to have dealt with the stations individually. For instance, Mr. Whipple gave the average number of solar halos in District V. (England S.) as 3 only. He (Mr. Marriott) was an observer in that particular district, and he observed some 20 halos or more during the year. He could not therefore agree with Mr. Whipple's method of discussion.

Mr. SYMONS said that the explanation of the anomalous distribution of frequency of rainy days in the paper arose from some observers only examining their rain-gauges when they think that there is rain in them, and so not getting the proper number of rainy days. It is always easy to ascertain how attentive an observer is by noticing the number of falls of ·01 in. and ·02 in. in the year. He thought that it would have been better to have dealt with the stations individually, the grouping being so misleading. For instance, England N.W., which was curiously represented by Llandudno, reported but 21 fogs, while England S., which included London, was credited with 62 fogs. He believed that many towns in Lancashire were more foggy than London, although Llandudno naturally was almost free from fog. He then referred to the question of hail-storms and thunderstorms, and related how the Hail Insurance Companies charge a much higher premium in Cambridgeshire than elsewhere, which agreed with the excess of electrical phenomena reported from Hillington, but was flatly contradicted by the table which gave the minimum frequency of hail for the Midland Counties of England. Mr. Symons pointed out other contradictions, and said that the tables indicated chiefly the relative watchfulness of the observers, and seemed to him also to indicate that it would be well if Mr. Marriott's visits of inspection could be rather prolonged.

Mr. WHIPPLE, in reply, stated that his intention in preparing the paper was to discuss the weather of the different parts of the country, not at particular places; hence his adoption of the district plan. He regretted extremely that the paper told unfavourable for the system of non-instrumental observations organised by the Society, and trusted that the publication of his paper might tend towards its improvement.

ELECTRICAL AND METEOROLOGICAL OBSERVATIONS ON THE PEAK OF TENERIFFE.

By Hon. RALPH ABERCROMBY, F.R.Met.Soc.

[Received November 8th, 1887—Read February 15th, 1888.]

I made a short trip to the Island of Teneriffe in the month of October 1887, and have now the honour of laying before the Society some of the results which I obtained in the following order :—1. Electrical; 2. Clouds, Cirrus, and Halo-forming sky; 3. The Shadow of the Peak; and 4. The vertical succession of Wind Currents.

1. Electrical.

By far the most important observations I proposed to make were those on the electrical condition of the Peak. All over the world, the normal condition of the atmosphere has been found to be that of a greater or less positive potential between a point above the earth and the surface of the ground itself. The only notable exception to this law was found in some observations made on the Peak of Teneriffe in the year 1856 with a gold-leaf electrometer. Then it was noted that the condition of the Peak was constantly resinous, or negative.

Some doubt has, however, been expressed as to whether the sign of the electricity was rightly given, and it was specially suggested that there might be great difficulty in getting a good "earth" on sun-burnt lava, in an exceptionally dry atmosphere. I therefore determined to examine the question with the far superior instruments now available.

I obtained, through the courtesy of the Meteorological Office, the loan of a portable Thomson's electrometer. Mr. Whipple, of Kew, kindly re-determined the scale of the instrument by means of Mr. de la Rue's chloride of silver battery, and gave me all necessary instructions. The instrument worked extremely well, but the fuses were indifferent, and gave some trouble in high wind and at high altitudes.

On the 6th October the Leyden jar at the base of the instrument received a charge at Kew of about 8,000 volts; but by the time the electrometer arrived at Orotava, at the base of the Peak, on 18th October, the charge had leaked down to 1,670 volts.

Fifteen sets of observations were made, nine at Puerto d' Orotava, 50 feet above sea level, and six at various altitudes up to 12,200 feet. Each set usually consisted of three series of—earth, air, earth—determinations. The height of the fuze may be taken at 5 ft. 5 ins. Every observation showed positive electricity of variable potential.

One of the Orotava sets had to be discarded. The mean of the remaining eight gave a positive potential of 188 volts; the highest being 193, the lowest 98 volts.

One day, when an ascent was made to the sharp edge of the old crater at the top of the great rock buttress called Mons Tigayga, an observation on the slope of the mountain at 3,800 ft. gave a potential of 99 volts, while on the crater edge itself, 7,100 ft., tension rose to 257 volts. The rock is a long, sharp, narrow edge, forming portion of the rim of an old crater with a precipitous cliff of 500 ft. on one side. The ground was broken lava, and seemed to be a little damp; still the earth readings given below were not so accordant as usual.

Electrometer observations, old crater edge (7,100 ft.), October 20th, 1887, 12.50 p.m.:—

Earth ...	...	7·49	7·48	7·15	Mean diff. 1·286
Air ...	...	5·96	6·15	6·17	= 257·2 volts.
Earth ...	...	7·48	7·38	7·45	

The figures give the readings of the head of the micrometer screw, not the potentials in volts, but the 1-100th turn of the screw was practically equal to a difference in tension of 2 volts.

A few days later the Peak was ascended. At 5,600 ft. on the slope of the mountain the potential was 111 volts.

At 5,800 ft. in the Cañadas, or irregular floor of the old crater, tension was 139 volts. The earth readings were extremely accordant, for five out of six gave the same number, 5·78, while the sixth determination was 5·68. The ground was pumice dust, and pretty dry, so I determined to try a suggestion of Mr. Whipple's to secure a good earth. An ordinary 66 ft. iron surveyor's chain was, therefore, run out, and connected by copper wire to the instrument, but not the slightest change was made in the earth readings. It was not, therefore, considered necessary to use the chain again, but the climatic conditions were different now to what they had been in July 1856, when the former observations were made. Now the wet bulb was only 7° below a temperature of 54°; then the depression was about 30°.

At the *Estancia de los Ingleses*, 10,500 ft.—a small natural platform on the slope of the main Peak—the potential fell to 118 volts. The sun was setting, and the dew falling so fast that the top of the electrometer box was quite wet. The ground was lava and pumice, but there could be no doubt of obtaining a good earth.

On the top of the Peak, 12,200 ft., the potential rose to no less than 549 volts. This was at 8 a.m. of October 24th. The wind was blowing at the rate of about 10 miles an hour from the North-east, and was doubtless the North-east Trade. No upper clouds were visible.

The dry and wet bulbs marked 31° and 26° respectively. There was a little white frost on the ground—pumice dust, sulphur, and whitened lava—and the earth readings were remarkably accordant, only differing by the 11-100th of a turn of the screw. The actual observations were as follows.

Summit Peak Teneriffe (12,200 ft.), October 24th, 1887, 8 a.m.:—

Earth ...	...	5·60	5·67	Mean diff. 2·745
Air ...	...	2·92	2·81	= 549 volts.
Earth ...	...	5·62	5·56	

One day at Orotava there was very heavy rain, and negative indications might possibly have been obtained; but I did not think it expedient to let the electrometer be drenched.

The results of all the observations point unmistakeably to the conclusion that during the month of October the electrical conditions of the Peak of Teneriffe were the same as in every other part of the world. The potential was moderately positive at the same distance from the ground even at considerable altitudes, but the tension rose enormously round a sharp point, and a projecting edge of rock.

2. Clouds, Cirrus, and Halo-forming Sky.

The general system of clouds was entirely different from that observed by Professor Piazzi Smyth in July and August 1856. Then a sea of cloud about 4,000 feet above the sea—drawn out into long rolls lying North-east and South-west—lay over the Ocean, but did not touch the land. Round the Island a thin collar of stratus was formed at about 3,000 feet, and stretching a mile or less from the land, so that a small gap was left between the two layers of cloud.

The conditions were quite otherwise in October 1887. The sea had its own cloud system, varying according to the weather, while the Island had another purely local cloud formation.

The more I see of mountains the more I am convinced that clouds and upper wind currents are far better studied on plains or out at sea than on mountain tops. Every hill is a source of local irregularities, which confuse the observer and give rise to erroneous conclusions.

The base of the cloud system in Teneriffe was usually between 3,000 and 4,000 feet above the sea. Viewed from below, a pretty well-defined line of mist could be seen; but when in the cloud at those levels, the line of the base was found to be really very irregular.

Some of the views, looking down into the villages, and the blue sea through the openings in this local cloud collar, were among the most beautiful cloud effects I have ever witnessed.

As a rule, the summit of the Island cloud system was of a cumuliform character; but at other times the cloud was stratiform, and on one occasion the cumulus tops became cirrified. This appearance I succeeded in photographing, and obtained the picture now exhibited to the meeting. The interest lies in the analogy which this appearance presents to the cirrifying of cumulus in front of rain or thunderstorms. There can be no doubt that the formation of this cloud is in all cases due to rising currents of damp air, but the full explanation cannot be given.

The number of halos observed in Teneriffe and the neighbourhood was very remarkable, for between October 13th and 25th no less than seven halos were noted. But the most curious and important fact was the extremely local formation of the halo-bearing sky. Ley has suggested the very suitable name of *cirro-nebula* for that high formless ice haze, by transmission through which halos are formed. In the neighbourhood of Teneriffe isolated patches of *cirro-nebula* used to float about, usually in direct connec-

tion with isolated masses of cumulus. The level of the ice-dust did not appear to be very high. At our surface temperatures an altitude of 14,000-15,000 feet would have been amply sufficient to lower temperature below the freezing point.

Each patch of *cirro-nebula* was certainly formed by the same cause that developed the passing shower or isolated lump of cumulus with which the ice-dust was associated. Now there is no doubt that cumulus in any form is the product of the condensation of a rising column of air, and so it can hardly be denied that the *cirro-nebula* is also the product of the same process. But at the same time it should be mentioned that *cirro-nebula* is sometimes associated with the flat layer of confused cloud which stretches over and beyond the top of mass of cumulus, and may be partially due to local non-cyclonic overflow. In several cases, too, I noticed that a sky which began cloudless at sunrise was covered first by a thin layer of some variety of halo bearing cirrus, and very little later, on the ordinary low level, by cumuliform land cloud. It always appeared to me as if the first breaths of vapour rising by evaporation and the sun's heat formed the thin icy cloud at a tolerably high level, and that then the abundant uptake of moist air during the day developed the low cumuliform clouds of water dust.

In England halos are developed either in front of cyclones or before thunderstorms, and only rarely in association with simple showers. I have also observed a good many halos associated with showers or thunderstorms near the Equator. The cause of the rain was, of course, totally non-cyclonic. At Teneriffe there was no reason to suppose that any of the halos were associated with cyclones. I believe that my observations are of some importance in the theory of cyclones.

My observations also not only entirely confirm the discovery first made by Professor Piazzi Smyth, that cloud is not formed at the junction of a South-west current and a North-east Trade, but they also show that there is no such condition as two currents in opposite directions flowing directly one over another. This will be further discussed under Section 4.

3. The Shadow of the Peak.

I was fortunate enough to witness the shadow of the Peak projected against the eastern sky at sunset, from the Estancia, at a height of 10,500 feet. Every stage of the phenomenon could be followed. First, the pointed shadow of the Peak lay sharply defined on the rugged floor of the old crater; then the apex crossed the sea to the horizon, and then the highest point rose out of the Ocean like another Peak, and just broke into the pink fringe which lined the horizon at sunset. The whole was now faint, and gradually died out as the sun went down lower, and the light became so dim from a slight haziness that the ordinary phenomenon of the shadow of the earth bounded by a pink fringe could not be seen rising out of the east.

There could not, however, be the slightest doubt of the accuracy of the generally received explanation, that the appearance of the shadow on or against the sky is simply part of the ordinary earth shadow, projected so clearly as to show well marked irregularities of the surface, such as isolated Peaks.

A similar phenomenon has frequently been described at Adam's Peak in Ceylon, and at Pike's Peak in Colorado.

4. Vertical Succession of Wind Currents.

The researches of Ley, Hildebrandsson, Vettin, and others, have conclusively proved that the vertical succession of the upper wind currents follows a very well defined law. If we stand with our back to the wind in the Northern Hemisphere, the wind will come more and more from our left side the higher we ascend. There are of course certain well defined exceptions to this rule, but in the vast majority of cases the law holds good.

But it has been taught in every text-book of meteorology or of physical geography for the last 50 years, that there is a return South-west current over the North-east Trade. I have made numerous observations in the Doldrum and Trade wind regions of the Atlantic, Indian, and Pacific Oceans, and have found that almost invariably the same law holds near the Equator as in the cyclone and anticyclone traversed districts of the Temperate Zone. The observations at Teneriffe tell the same story. Whether the vertical succession was normal or abnormal, there was almost always a regular progressive increase in the angle between the surface and the highest current, if any complication of land and sea breezes was left out.

It seems, therefore, that the old idea of a South-west current flowing immediately over a North-east Trade cannot be maintained. It is easy to see how the idea originated. People went to the top of the Peak of Teneriffe and of Mouna Loa in the Sandwich Islands, and found a South-west current at those heights, but they had not then realised the importance of looking at the motion of intermediate layers of air.

The following are examples of the screw systems of vertical succession of the upper currents :—

October 22nd, 1887, 8 a.m. Surface wind South; land breeze? Low clouds, West; high cirrus, North-north-west.

October 23rd, 5.30 a.m. Surface, South; land breeze? Low clouds, East; high cirrus, West-north-west. This is an instance of abnormal vertical succession.

The North-east Trade wind is associated with the continual presence of an enormous stationary anticyclone over the Southern portion of the North Atlantic Ocean, and the air circulates around this high-pressure system the same as around any other anticyclone further North in the manner of a complicated screw.

The conception to which we are now driven is that, as a rule, air currents do not flow over one another in contrary directions, but that the general circulation of the atmosphere from the Equator to the Pole is carried on by means of the more or less circular systems of eddies known as cyclones and anticyclones.

It is of course far more difficult to picture to ourselves this latter condition of things, but there can be no doubt that the modern view is more correct than the older opinion of currents and counter-currents.

Summary.

The results of this paper may be summarised as follows :—

The electrical condition of the Peak of Teneriffe was found to be the same as in every other part of the world. The potential was moderately positive from 100—150 volts, at 5 ft. 5 ins. from the ground even at the considerable altitude of 10,500 feet; but the tension rose to 549 volts on the summit of the Peak, 12,200 ft., and to 247 volts on the top of the edge of the old crater, 7,100 feet.

A large number of halos were seen associated with local showers and cloud masses. The necessary ice-dust appeared to be formed by rising currents, while the weather was non-cyclonic.

The shadow of the Peak was seen projected against the sky at sunset.

The idea of a South-west current flowing directly over the North-east Trade was found to be erroneous. There was always a regular vertical succession of air currents in intermediate directions at different levels from the surface upwards, so that the air was always circulating on a complicated screw system.

NOTE ADDED JANUARY 1888.

Since this paper was written Professor Michie Smith has called attention to the fact that in Madras at least a negative electrification of the air was a normal, and not an abnormal condition, for many hours of the day at certain seasons of the year. This appears to occur with hot, dry West winds, and the electricity is often of a very high negative potential.

With regard to Teneriffe, the climatic conditions of the Peak in the month of July, when visited by Professor Piazzi Smyth, are very different from those in October, when I was there. In the summer months the lava is hot and parched, while the air is almost unmeasureably dry.

DISCUSSION.

THE PRESIDENT (Dr. Marcet) said he had spent three weeks in the island of Teneriffe in 1878, and was therefore able to make some remarks upon the observations and conclusions of Mr. Abercromby. He was particularly interested with what had been said concerning the electrical conditions of the air at different heights. It was obvious that a person who ascended to the top of the Peak of Teneriffe with an electrometer was in the best position to make observations of the amount and condition of the electricity contained in the atmosphere, as such observations required to be as free from earth influence as possible, and the island of Teneriffe, from its isolated situation, offered great advantages in this respect. There was no doubt that the hygrometrical condition of the atmosphere had a good deal to do with the amount of electricity present. The air in the month of October, when Mr. Abercromby was there, must have been very damp compared with its state in the month of July when he (Dr. Marcet) visited the island; the difference between the dry and wet bulb thermometers was then frequently as much as 30°, and the sand was too hot to be touched. There was great radiation at night, water in a vessel left standing on the ground being on several occasions found frozen into a solid mass in the morning. He believed that if he had had an electrometer with him at the time he visited the island he would have recorded a very high electrical tension. As to the cloud forms, it was evident that those observed in October were quite different from those to be seen in July or August. Viewed from the Peak, the clouds very much resembled a rolling sea surface, presenting an exceedingly beautiful sight. The surface of these clouds was frequently unbroken; on one occasion, a rent or large aperture

appeared in the uniform cloud surface into which white masses of cumulus appeared to descend, a remarkable phenomenon recalling a gigantic waterfall. He found on inquiries that this broken place in the otherwise uniform cloud surface was immediately over the only damp spot in the island, and the waterfall appearance seemed to be caused by the damp air rising on account of its comparative lightness, thereby producing a relative vacuum into which the clouds above that spot were precipitated. He had seen the shadow of the Peak projected on the sky at sunset on many occasions during his stay on the Peak, and a very striking and beautiful phenomenon it was. He had noticed a peculiar smoke-like appendage from the top of the shadow which he could not understand. He had witnessed a similar phenomenon last summer at Zermatt; on that occasion a distinct shadow of the Matterhorn, cast by the moon, was seen reflected on the sky, while on one side in the darkness was the real Matterhorn. There were very few clouds at the time, and he could not understand upon what the shadow was actually thrown. Regarding the direction of the wind on the Peak, he certainly had noticed that the wind was more Westerly at the top than at the bottom. However, he understood Mr. Abercromby had found there was no such return wind at a high level blowing in an exactly contrary direction to the Trade Wind, as was generally supposed. This view rather upset the well-known old established law relating to Trade Winds, and the high level return current from the Equator to the Poles, and it was difficult to understand what became of the North-east Trade if it did not return in the manner hitherto believed.

Mr. ARCHIBALD said there was no doubt that Mr. Abercromby's electrical observations aided in showing the general existence of a positive potential, but they did not show the actual conditions of the upper atmosphere, as all the observations were made on the ground. The only really satisfactory way to determine the electrical or other conditions of the higher regions of the atmosphere was by means of balloons or some similar method. He had an idea that useful observations might be made by means of instruments hung on wires stretched across valleys. He thought that there was not very much gained by Mr. Abercromby's electrical observations, except that they served to show the general conditions on a particular day or days. He agreed with Mr. Abercromby that the uprising current in front of a cyclone might produce lower cumulus, but he could not agree that cirro-nebula was also produced by this ascending air current, and he thought that Mr. Abercromby's one observation on this point could not be permitted to upset the generally accepted doctrine regarding the formation of this cloud. With respect to the vertical succession of air currents he said that the theory of cyclone motion plainly showed that they changed in direction on ascent above the ground by gradually screwing round, and Mr. Abercromby's observations so far confirmed the theory by showing that the changes in air motion experienced in ascending the Peak were gradual and not sudden.

Mr. ABERCROMBY, in reply, said that he could not explain the origin of the curious appendage to the shadow mentioned by Dr. Marcet, but he had seen a similar phenomenon at Adam's Peak, in Ceylon. The question as to the reflection of the shadow was a difficult one; but the material on which the image was formed must be sought for in earth and water dust suspended in the atmosphere. He did not say that there was no South-westerly upper wind, as Dr. Marcet seemed to have understood; but what he stated was, that the old idea of directly opposed layers or currents of air moving immediately over each other was erroneous, as the air was found to circulate on the screw principle. With regard to the question of the electrical condition of the higher atmosphere, he believed that the observations by means of balloons afforded the only way of actually settling the matter. His conclusions regarding the formation of cirro-nebula were not based upon a solitary observation, but were the result of investigations and observations he had made during the past fifteen or twenty years. He believed that cirro-nebula was usually produced by rising currents, and not brought by overflow from the vortex of a cyclone. Among other reasons, the halos seen in Teneriffe, and many others he had observed near the Equator, were not associated with cyclones at all. In one of the photographs exhibited from near Teneriffe a heavy mass of cumulus formed locally over the Peak, thinned out seawards, first into strato-cumulus, and then into cirro-cumulus and fibrous cirrus. This was exactly analogous to the cloud mass over the centre of a cyclone thinning out to a cirrus-fringed edge.

RAINFALL OF SOUTH AFRICA,

1842-1886.

By WILLIAM B. TRIPP, M.Inst.C.E., F.R.Met.Soc.

(Plates I. and II.)

[Received November 7th, 1887—Read February 15th, 1888.]

1. *Particulars of Stations.*

The Rainfall stations possessing records of 10 complete years and upwards are chiefly situated in the South-western, Southern, and Eastern portions of South Africa, including the greater part of the Cape Colony and Natal.

The chief sources of information employed have been the published reports of the Cape Town Meteorological Commission and the records of the Royal Observatory. Mr. Gamble, M.A., M.Inst.C.E., kindly furnished the author with additional particulars, and the records of the Natal Observatory have been consulted for later years.

When a month or year is named it is understood that it is included in the discussion.

The area embracing the stations has been divided by the author for geographical and meteorological reasons into 3 main divisions, viz. *West*, containing 8 stations, *East*, 19, and *Natal*, 4; total 31. Their names and further particulars will be found in Tables I. and II. Records have only been obtained for one station, the D'Urban Observatory, in Natal, for the years 1885-6. (Plate I.)

From 1842 up to 1850 records are found at the Royal Observatory alone, in 1851 others were commenced, and the numbers began to increase considerably in 1862. The above mentioned Commission's report for 1886 includes rainfall records from some 275 stations.

The older records, excepting of course those of the Royal Observatory, are much broken, and from 1869 to 1875 several blanks occur in the records, especially of the western parts. The next longest continuous record to that of the Royal Observatory is that of Graaff Reinet, in the Eastern Division, which has 26 complete years up to 1886. The Town House, Cape Town, has 35 years, of which 25 are continuous.

One of the least satisfactory of the records appears to be that kept at Simon's Town in the Cape Peninsula, which has 11 complete years, the longest continuous series of which consists of 5 years only, and the probable extreme year both of wet and dry are wanting.[1] The published records of Merebank,

[1] Bredasdorp, Mossel Bay, Lower Nels Poort, and Kimberley records are also very defective, not including 1876, the wettest year in the East, with other important omissions. The Natal observations are fragmentary in the earlier years, of these Pietermaritzburg is best.

in Natal, though only containing 9 years, from 1866 to 1874, have been made use of.

The elevation of these stations above sea-level varies from 20 feet, that of Simon's Town, to 4,400 feet, that being the elevation of Aliwal North, in the Eastern Division.

The stations are in some cases numerous within a comparatively small area, as the groups in the Cape Peninsula, about Graaff Reinet, and near Camfer's Kraal; in most cases, however, they are much further apart: from Worcester in the West to Amalienstein in the Eastern Division is some 115 miles, and from thence to Camfer's Kraal is about 125 miles. Some of the South Coast stations are, however, nearer to Amalienstein; from Aliwal North to Pietermaritzburg the nearest Natal station is about 230 miles.

The yearly falls of rain at different stations vary from 82·82 ins. at Durban to 3·10 ins. at Camfer's Kraal, and the means vary from 54·17 ins. at Bishop's Court to 8·36 ins. at Camfer's Kraal.

Calling the means 100, the percentages of the maxima and minima vary as follows:—

Maxima... Highest, Worcester 196, Lowest, { Gardens Cliffe 124 per cent. / Simon's Town 121 ,,

Minima... ,, Clanwilliam 76, ,, Braakfontein 36 ,,

Taking the maxima at 100, the percentage of the minima vary from 58 at Clanwilliam and 62 at Simon's Town to 22 each at Worcester, Braakfontein, and Camfer's Kraal, these ratios indicating the least and greatest range of yearly fall respectively.

The means of the average yearly falls at the stations constituting the three divisions are, West 27·34 ins., East 17·06 ins., Natal 38·21 ins.; all stations 22·44 ins.—the existing records having been taken as they stand, and their arithmetical means computed.

The following particulars of the amount of the mean annual fall may here be interesting.

1. Along mountain ranges, such as Table Mountain in the Cape Peninsula, and the Katberg and Amatola Mountains in the South-east part of the Cape Colony, the yearly fall amounts in some cases to from 50 to 70 ins.

2. In parts covered with forests, as the T'Zityikama on the South Coast, and in Natal, the fall is from 30 to 50 ins.

3. A large part of the Eastern division of the Cape Colony, a strip along the mountains near, and parallel to, the South Coast, and the South-west parts in the vicinity and to the North-west of the Cape Peninsula, have a yearly fall of from 20 to 30 ins. The boundary line of this portion trends inland towards the North, apparently including Molepolola in Bechuanaland.

4. A band of country along the inland side of the last named areas, and the Western central portion of the South Coast, get from 10 to 20 ins.

5. A patch of the Great Kanro lying between the Zwarteberg and Nieuwveldt Mountains and the extreme North-west regions of the Cape Colony appears to get an average yearly fall of under 5 ins.

The records in the North-west and West-central parts do not at present extend over a great number of years.

In order to form a comparative scale of rainfall proportional for each record, the differences between the means and maxima and minima respectively of all stations have each been divided into three equal parts, and these have been so apportioned as to form a scale,—without reference to the different depths, in inches, of the amounts of yearly fall at the various stations,—of which scale the component degrees of yearly rainfall have been denominated, "Very wet," "Wet," "High mean," "Low mean," "Dry," and "Very dry" respectively.

2. *Chronological Succession of Wet and Dry Years.*

In order to obtain some idea of the average proportional rainfall over each of the main divisions and over the whole area in different years, and owing to the varying depths of rain falling at different stations and to the breaks in the records, it has been found necessary to eliminate altogether in such calculation the depths of fall in inches, and to calculate for each station a series of numbers representing proportionally the degrees of fall given above, and calling the greatest recorded fall 80w, and the least 1D, and giving the intermediate falls their proper proportional values respectively, as follows:—Very wet 80-26, Wet 25-21, High mean 20-16, Low mean 15-11, Dry 10-6, and Very dry 5-1.

From tables so constructed Table III. has been found, giving the average proportional degrees of yearly rainfall from the means of the proportional numbers of all the stations recorded for each year.

Figs. 1-3 (Plate II.) illustrate the yearly distribution of rainfall.—Fig. 1, for 1872, a uniformly wet year at nearly all stations; Fig. 2, 1878, wettest recorded year in the West, very dry in the East and Natal; and Fig. 3, 1886, a year with a variable fall, which at most stations was below the mean, but which was extremely heavy at the South-eastern stations, at three of which it was the wettest recorded year. The Author has constructed similar diagrams for each year since 1850, the more interesting of them begin with the year 1862.

The falls of rain in the different divisions of South Africa are in frequent contrast to each other in particular years.[1] Within the Eastern and other divisions, various stations form themselves apart from the rest into wet and dry groups, although in the aggregate of years the stations of each division will agree together more nearly than with those of other divisions. Thus Amalienstein, situated between East and West, agrees with Eastern stations in the proportional amount of its rainfall in some 60 or 70 per cent. of the recorded years.

The South-eastern stations of the Eastern Division have formed the nucleus of important wet groups, particularly in the years 1867, 1870, 1880, 1886, and other years; this is chiefly characteristic of Port Elizabeth, Uitenhage, Somerset East, and Graaff Reinet and its adjoining stations, all of which are included in the Basins of the Fish and Sundays Rivers; indeed the year 1876, the wettest recorded year in the Eastern Division, was an amplification of

[1] For instance, 1878, mentioned above.

this phenomenon, both West and Natal, situated on each side, having been dry.

Stations nearest to each other frequently differ much in degree of rainfall, but the falls will be found to differ more in degree than in season, and their monthly diagrams will frequently be found to be very similar. This is noticeable in the stations of the Cape Peninsula and the Camfer's Kraal group. In many cases, doubtless, the physical features of the country may have something to do with this grouping and varying fall. This may be noticed in the case of the grouping of the South-eastern Stations above referred to, which lie between the Great Winterberg in its spur and the Katberg and Amatola Mountains on the North, and the Cockscomb and Winterhoek Mountains near Port Elizabeth.

Broadly, the 25 years, 1861-86, may be divided as follows :—

1. Uniformly dry years, 1865, 1861, 1864, 1873, in order of dryness.
2. ,, wet ,, 1872, 1868 in order of wetness.
3. West, very wet, East, and Natal dry, 1878, 1862, 1877, 1869.
4. East and Natal wet, West dry, 1874, 1879.
5. Other years with more irregular grouping.

A more detailed classification is given in Table IV.

Previous to 1860 the stations possessing records were so few that it is difficult to group them properly.

The most recent and best recorded wet cycle first appeared from 1872-74 in Natal. In the East it began in 1872, and culminated in the very wet year 1876, above referred to. In the West it was represented by the years 1876-78, the latter of which was an extraordinarily wet year in that division, thus presenting a kind of progression from the East to the West.[1]

The years above the mean, averaging the stations, have been—

1. In the West, 1842-3, 1849-50, 1852, 1855, 1857-60, 1862-3, 1869-70, 1872-3, 1876-8, 1883-85 ; the wettest years having been 1878, 1859, and 1862, in order of wetness, and the wettest consecutive three years, 1876-78.

2. In the East, 1855-57, 1860, 1863-4, 1867-8, 1870-72, 1874-6, 1879-81, 1886; the greatest falls having been in the years 1876, 1863, 1860, and 1874, and the wettest consecutive three years, 1874-76.

3. In Natal, 1854-56, 1863-4, 1868, 1872-5, 1879-80, 1883-84; wettest years, 1856, 1854, 1872, 1868, and 1855, in order of wetness, and three wettest consecutive years, 1854-56.

4. Taking East and Natal together, there having been no records in the East in 1854, the corresponding wet sequence to that of Natal in 1854-56 is not complete, and the next three wettest recorded are 1874-76.

5. Taking all stations, the wettest year was 1872, and the next in order of magnitude of fall was 1874, 1870, 1876, and 1863.

The years below the mean have been—

1. In the West, 1844-48, 1851, 1853-4, 1856, 1861, 1864-68, 1871,

[1] During this period the last heavy floods occurred in the rivers of the Eastern Division of the Cape Colony. The year 1886 was again very wet at some of the Eastern Stations, as before mentioned, after many years of drought.

1874-5, 1879-82, 1886. The driest years have been 1880, 1864, 1865, and 1879, and the driest consecutive three years, 1864-66.

2. In the East, 1851-2, 1858, 1861-2, 1865-6, 1869, 1873, 1877-8, 1882-5. The driest years having been 1862, 1852, 1877, and 1865, and the driest consecutive three years, 1883-5.

3. In Natal, 1851, 1858-62, 1865-67, 1869-71, 1876-78, 1881-2, 1885-6. Driest years, 1861, 1878, 1886. Driest three consecutive years, 1859-61.

4. Taking East and Natal together, the three driest consecutive years were 1860-62. Taking all stations, the driest years were 1865, 1861, 1864, 1877, 1866, and 1878; three driest consecutive years, 1864-66.

It is a very general occurrence that a very wet year is succeeded by a very dry one.

Additional particulars as to wet and dry years are given in Table IV.

3. *Series of consecutive Years above and below the Mean.*

Taking the whole of the recorded years at all stations added together it appears that the years with rainfall below the mean are about 1⅛ of those above the mean. The percentages of years below the mean range at particular stations from 260 per cent. at Worcester to only 44 per cent. at Queen's Town out of the 18 years recorded at that station, a circumstance which has, doubtless, much to do with the excellent sheep pastures for which the neighbourhood of that station is celebrated.

The longest sequence of years with rainfall above the mean has been six years, at the Royal Observatory from 1881-86 and Garden's Cliffe from 1879-84.

The longest sequence below the mean has been at the Royal Observatory eight years, from 1851-58, and King William's Town eight years, from 1878-85, or perhaps nine years, including the year 1877, which was a dry year in the East, although records for that year were not completed at King William's Town. This station has, therefore, experienced the longest succession of years of the recent drought, while Somerset East has had only one year, 1883, below the mean since 1879, 1877 and 1878 having been also below. Glen Nande's Berg had four exceedingly dry years, 1882-85.

It may be well here to mention that the author has made a recent calculation of the mean yearly volume of water draining into the Ocean from the Cape of Good Hope south of the Orange and Vaal Rivers, being most probably at least some eight or nine hundred thousand million cubic feet, the value of which, to a country like South Africa, making it a matter of great importance as to whether this large volume of water is properly utilised, and whether proper steps are being taken to ascertain by rain and river observations, what such resources consist of, in order that they may be taken advantage of to their full extent.

4. *Seasonal Distribution of Monthly Maxima.*

It is now well known that the rains which reach the Western and Eastern shores respectively of South Africa are due to independent meteorological conditions; those in the West being chiefly brought by the North-west or Anti-trades in autumn and winter, and those in the East by the South-east or Trades in summer and spring.

January, February and March are here considered as Summer; April, May, June, as Autumn; July, August, September, as Winter; and October, November and December, as Spring.

Taking the maxima of means of rainfall over a long series of years at each station, we find that their distribution is somewhat as follows:—Over the chief portion of the Eastern division the maxima occur, monthly in March, quarterly in summer, and half-yearly in summer and spring. The Western and South-western parts get it monthly, in May, June and July, chiefly; quarterly in autumn; and half-yearly in two divisions, in summer and autumn, and further West in autumn and winter. On the South Coast the maxima chiefly occur monthly, in March; quarterly, in winter; and half-yearly. A double maximum occurs in winter and summer; and this last phenomenon occurs also at East London on the South-east Coast, and apparently forms a kind of compromise between the two opposing climates.

Between the main divisions other, chiefly intermediate, seasonal conditions prevail. Amalienstein, before referred to, agrees with the East in getting its quarterly maximum in summer, and with the West in having its second largest fall in autumn; its wettest month is May, the intermediate month between March, characteristic of the East, and July, of the West.

A peculiar feature in the rainfall for 1886, Fig. 8, is, that the excessive fall of July in the East was in opposition to the usual seasonal distribution of fall, but it was very welcome notwithstanding, these winter rains favouring the growth of many things, and notably of wheat.

For the monthly maxima the Author has chiefly relied on the means contained in the *Meteorological Commission Report* for 1883, also Mr. Gamble's paper, *Quart. Jour. R. Met. Soc.* January 1881, and other sources.

Fig. 4 (Plate II.) gives a plan illustrative of the mean half-yearly distribution of maximum rainfall.

5. *Extent over which Monthly Rains prevail.*

Although, however, these maxima chiefly occur, as above stated, in particular years, the seasonal rains often overstep these limits, and the autumn and winter rains of the South-west appear to be felt not only at South-east Coast ports, but at inland Eastern stations and right up to Natal, while the customary summer and spring rains of the latter divisions can be traced down to the Cape Peninsula.

The author has not the daily records to refer to, but he has constructed diagrams of the usual monthly returns for several of the years under consideration, and from the monthly coincidences of excessive fall shown by these he has constructed Table V. of notes on coincidences between monthly rains in different parts of South Africa.

Table VI. gives the monthly rainfall for 1872, which was the most uniformly wet year recorded over the area under consideration.

In the early part of the year heavy seasonable rains were experienced at Aliwal North, which appear to have been chiefly felt at Northern stations, as there is little trace of them at Graham's Town, and the figures of Morebank show a depression. At Camfer's Kraal there was a slight coincidence in

the January rains; and in March there was an excess at that station, the Royal Observatory, and Clanwilliam. May had a heavy seasonable fall at the Royal Observatory and Clanwilliam, which was felt at Camfer's Kraal, and attaining a maximum at Graham's Town, dwindled to small proportions at Aliwal North, and did not reach Merebank. The heavy fall in the West, during August, shows some signs of a coincidence at Graham's Town, which is frequently in correspondence with Port Elizabeth; there is not much sign of it at Aliwal North, and none at Merebank. In November there was a heavy seasonable fall at Merebank, coincidences of which are seen in all successive values in diminishing order down to the West, in fact the values for the last three months of the year are very similar.

The inference drawn by the author is that rains which occur at the same time with seasonal rains on either coast are intimately connected with such rains, and it would be an interesting inquiry to ascertain how they are propagated and in what manner they progress.

These coincidences are more frequently seen, so far as the author has examined the question, in the case of rains, seasonable in the East and Natal being represented in the South-west, than *vice versâ*, in the proportion of about 129 to 100, as regards Natal and Cape Peninsula rains, and in the case of Eastern and South-western rains as about 107 to 100.

In these cases of coincidence those quarterly rains occurring from January to March in the East, and those from April to June in the West, appear to be represented by coincidences more frequently than those from July to September in the West, and October to December in the East, in the proportion of 2 to 1.

6. *Comparison of Curves of Rainfall with those of Sunspot Energy.*

The numbers given in Table VII. are Wolf's sunspot numbers, taken from the Table contained in Mr. Scott's *Elementary Meteorology*, additional numbers having been kindly supplied to the author by Mr. Ellis, F.R.A.S., F.R.Met. Soc., of the Royal Observatory, Greenwich. The rainfall values are the proportional numbers described above as having been calculated by the author for all stations, in order to obtain a mean of the fall in the different divisions.

Owing to the fact alluded to above of the close succession of very wet and very dry years, it has been thought desirable to equalise in some degree these extreme yearly fluctuations of the fall, on the same principle that an observer would attempt to eliminate the extremes of a column of mercury pumping violently under the influence of intermittent pressure, or those of a tidal gauge under the influence of rapidly succeeding waves masking the average curve of the required tidal wave. The process adopted in the present case consists of making the values for each year the means of the proportional numbers for itself and those of the two preceding years, the values for each year being therefore the means of three years. This simple expedient would naturally suggest itself to anyone who had been engaged in observations of the character above referred to, although the author has never seen it applied to its present purpose. He has, however, been informed by

TABLE I.—PARTICULARS OF RAINFALL STATIONS POSSESSING RECORDS OF 10 COMPLETE YEARS AND UPWARDS.

Stations.	Height above Sea-Level.	First and Last Complete Years.	Greatest No. of continuous Complete Years.	Total No. of Complete Years.	Range of					Percentages.		
					Wet.	Mean.			Dry.	Mean = 100.		Max. = 100.
					Wettest.	High.	Mean.	Low.	Driest.	Max.	Min.	Min.
WEST.	Ft.				Ins.	Ins.	Ins.	Ins.	Ins.			
Clanwilliam	300	1870–86	9	13	11·21	9·48	8·62	7·92	6·53	130	76	58
Groote Port	..	1866–86	21	21	24·77	20·40	18·22	16·40	12·75	136	70	51
Town House (Cape Town)	50	1851–86	25	32	43·10	32·33	26·95	23·87	17·70	160	66	41
Royal Observatory	37	1842–86	45	45	41·02	30·52	25·26	22·75	17·71	162	70	43
Bishop's Court	250	1866–86	11	15	77·87	62·07	54·17	48·81	38·08	144	70	49
Wynberg	250	1857–86	10	21	68·50	50·99	42·23	37·31	27·47	162	65	40
Simon's Town	20	1862–86	5	11	37·35	33·04	30·89	28·29	23·09	121	75	62
Worcester	780	1862–86	10	18	24·32	16·37	12·40	10·04	5·33	196	43	22
Extremes, Totals & Means	..	1842–86	45	176	77·87	62·07	27·34	7·92	5·33	196	43	22
EAST.												
Bredasdorp	250	1867–86	8	10	25·48	21·09	18·90	16·54	11·81	135	62	46
Amalienstein	1500	1868–86	19	19	21·19	16·14	13·61	11·96	8·64	156	63	41
Mossel Bay	105	1862–86	9	11	22·81	18·42	16·23	14·67	11·55	141	71	51
Braakfontein	4100	1873–86	14	14	15·91	11·81	9·76	7·68	3·52	163	36	22
Lower Nels Poort	3100	1863–86	9	13	16·58	12·30	10·15	8·26	4·48	163	44	27
Camfer's Kraal	3000	1867–86	18	19	13·81	10·18	8·36	6·61	3·10	165	37	22
Rietfontein	2270	1868–86	16	18	22·03	15·01	11·51	9·37	5·09	191	44	23
Graaff Reinet	2500	1861–86	26	26	24·30	17·96	14·78	12·18	6·96	164	47	29
The Glen, Nande's Berg	..	1875–86	8	10	20·93	17·59	15·92	14·53	11·75	131	74	56
Goliad's Kraal	3500	1863–86	14	23	21·53	16·48	13·96	11·37	6·18	154	44	29
Wellwood	4000	1875–86	12	12	19·37	15·13	13·01	11·36	8·07	149	62	42
Somerset East	2500	1870–86	11	16	38·64	28·10	22·82	18·99	11·32	169	50	29
Uitenhage	200	1860–86	13	24	22·37	17·72	15·39	13·08	8·47	145	55	38
Port Elizabeth	180	1867–86	20	20	33·65	26·66	23·16	20·54	15·31	145	66	45
Graham's Town	1800	1851–86	9	21	40·82	33·36	29·63	26·22	19·38	138	65	48
King William's Town	1314	1868–86	9	18	37·26	29·19	25·16	21·69	14·76	148	59	40
Queen's Town	3500	1873–85	13	13	28·34	23·33	20·83	18·11	12·66	136	61	45
Aliwal North	4400	1867–86	20	20	31·93	26·88	24·35	21·90	17·00	131	70	53
Kimberley	3950	1875–86	10	11	30·30	21·16	16·58	14·17	9·34	183	56	31
Extremes, Totals & Means	..	1851–86	26	318	40·82	33·36	17·06	6·61	3·10	191	36	22
NATAL.												
Pietermaritzburg	2100	1854–67	10	13	50·98	39·96	34·46	30·44	22·41	148	65	44
Gardens Cliffe	2270	1867–84	18	18	46·18	40·15	37·14	33·41	25·95	124	70	56
D'Urban	130	1851–86	14	18	82·82	56·35	43·17	38·19	28·24	192	65	34
Ottawa	300	1870–84	10	14	56·71	44·28	38·06	34·22	26·53	149	70	47
Extremes, Totals & Means	..	1851–86	18	63	82·82	56·38	38·21	30·44	22·41	192	65	34
Do. All Stations	..	1842–86	45	557	82·82	62·07	22·44	6·61	3·10	196	36	22

TABLE II.—Particulars of Rainfall at 15 Stations, possessing Records of 10 complete Years and upwards.

Stations.	1842.	1843.	1844.	1845.	1846.	1847.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.	1864.
West.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Clanwilliam	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Groote Port	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Town House (Cape Town)	..	..	..	..	..	..	..	..	..	26·37	31·46	29·75	28·20	32·40	26·35	33·55	..	..	..	..	28·75	26·90	17·70
Royal Observatory	26·27	24·82	18·78	20·91	22·50	22·38	23·25	24·62	33·47	20·31	23·19	21·22	20·05	24·57	19·48	22·05	24·27	36·72	29·12	25·44	32·01	25·60	18·92
Bishop's Court	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Wynberg	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	37·96	42·41	59·80	35·40	34·62	68·50	..	34·23
Simon's Town	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	36·09	33·94	23·09
Worcester	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	21·24	14·55	8·79
East.																							
Bredasdorp	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Amalienstein	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Mossel Bay	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	11·55	..	..
Braakfontein	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Lower Nels Poort	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	16·58	12·06
Camfer's Kraal	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Rietfontein	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Graaff Reinet	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	12·41	6·96	18·35	13·55
The Glen Nande's Berg	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Goliads Kraal	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	16·98	13·83
Wellwood	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Somerset East	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Uitenhage	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	19·21	12·51	12·40	19·22	15·00
Port Elizabeth	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Graham's Town	..	..	..	..	..	..	..	..	..	25·46	22·14	..	..	32·04	33·27	30·99	26·08	..	..	..	..	..	..
King William's Town	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Queen's Town	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Aliwal North	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Kimberley	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Natal.																							
Pietermaritzburg	..	..	..	..	..	..	..	..	..	..	..	..	50·56	42·77	50·98	..	27·42	28·40	30·60	22·41	29·97	34·66	37·31
Garden's Cliffe	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
D'Urban	..	..	..	..	..	..	..	..	..	41·91	..	..	..	82·82	..	..	..	..	..	..	..	..	..
Ottawa	..	..	..	..	..	..	.	..	..	..	..	..	..	..	..	..	..						

Stations.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.
West.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Clanwilliam	..	..	..	..	..	10·24	8·61	11·21	..	..	..	..	..	10·95	8·04	6·89	6·53	7·46	9·82	6·58	8·54	7·63
Groote Port	..	22·21	16·00	17·95	22·16	24·07	15·61	19·07	18·31	16·31	14·70	18·96	22·90	24·77	13·19	12·75	17·88	14·08	23·16	18·90	16·54	13·11
Town House (Cape Town)	21·00	23·90	29·55	26·35	33·35	33·60	22·15	29·95	25·45	24·15	21·10	25·40	28·65	43·10	22·20	19·25	31·00	31·26	22·37	23·72	22·74	20·78
Royal Observatory	18·67	19·21	22·96	19·95	32·34	28·06	20·10	29·32	23·77	26·20	25·72	26·64	35·56	41·02	18·74	17·71	25·61	29·31	32·06	28·29	27·92	27·79
Bishop's Court	..	44·49	42·92	45·97	59·05	..	..	..	..	..	..	51·16	64·37	77·87	44·97	38·08	55·59	55·97	64·90	56·65	57·73	52·82
Wynberg	36·57	33·57	29·32	37·26	..	..	..	..	..	..	..	..	50·22	63·05	34·52	27·47	37·48	43·46	52·15	43·40	42·75	42·77
Simon's Town	24·82	..	..	..	28·64	..	..	..	..	..	..	28·60	..	..	..	..	..	30·63	37·35	36·02	30·77	29·80
Worcester	5·33	8·82	11·30	11·31	20·33	16·75	11·48	..	..	..	..	..	..	24·32	..	9·74	7·40	10·43	10·39	7·61	11·92	11·40
East.																						
Bredasdorp	..	..	16·32	11·81	..	..	..	..	..	..	..	..	..	..	18·60	25·48	16·74	19·54	16·88	23·80	18·42	21·38
Amalienstein	..	..	..	21·19	13·24	15·74	11·91	14·15	10·73	10·74	17·48	20·60	9·76	13·10	13·17	12·31	8·64	10·86	15·93	13·82	12·88	12·39
Mossel Bay	..	..	..	19·16	..	..	..	..	..	..	..	..	..	17·59	14·81	16·62	13·90	15·14	13·77	16·88	22·81	16·30
Braakfontein	..	..	..	..	..	..	..	..	9·46	11·59	14·75	15·91	4·46	7·28	11·24	7·79	12·31	8·87	3·52	9·64	10·71	9·12
Lower Nels Poort	10·61	9·06	..	..	..	..	..	..	..	..	..	..	..	6·91	11·66	8·51	9·66	12·35	4·48	9·16	12·09	8·86
Camfer's Kraal	..	..	9·34	..	6·18	7·80	9·40	11·15	6·88	10·16	13·10	13·81	3·84	6·51	8·94	7·19	8·01	8·93	3·10	7·94	9·19	7·42
Rietfontein	..	..	..	6·92	12·91	16·95	11·06	16·47	7·35	11·58	20·45	22·03	8·04	10·93	9·92	6·62	5·09	12·29	8·65	..	9·64	10·23
Graaff Reinet	8·20	14·24	18·20	16·46	13·84	18·42	16·47	15·14	10·24	21·70	17·47	21·01	10·91	9·98	13·72	16·20	15·09	14·08	11·38	11·53	14·54	24·30
The Glen Nande's Berg	..	..	..	..	..	..	..	..	..	..	16·07	20·44	..	..	17·18	16·26	20·93	12·83	12·62	11·75	12·78	18·31
Goliads Kraal	6·18	13·85	17·06	13·95	11·01	21·06	8·73	..	8·57	19·75	14·63	21·53	9·33	11·11	16·07	13·43	20·51	12·68	9·58	11·09	11·34	18·83
Wellwood	..	..	..	..	..	..	..	..	..	..	14·50	17·17	9·08	8·07	13·89	12·27	17·66	12·01	9·64	10·58	11·86	19·37
Somerset East	..	..	..	..	..	25·34	20·51	19·00	12·28	21·04	..	27·54	11·32	15·92	26·42	29·52	25·93	25·17	20·05	23·17	23·33	38·64
Uitenhage	8·47	11·88	18·02	15·89	16·40	18·34	11·02	16·30	..	..	18·26	17·48	..	18·15	17·91	22·37	13·63	14·49	12·74	10·38	13·01	16·25
Port Elizabeth	..	..	33·65	19·78	23·00	30·38	24·73	28·60	20·15	30·33	23·30	22·00	15·31	24·83	19·99	24·80	22·52	17·27	23·17	19·71	17·14	22·56
Graham's Town	..	..	..	30·43	24·25	..	..	39·65	..	40·82	20·18	27·57	..	19·38	29·91	36·61	33·28	28·78	23·83	26·00	31·78	39·87
King William's Town	..	..	..	31·08	23·41	27·85	27·52	30·01	21·22	37·12	22·76	37·26	..	14·76	24·08	24·92	24·72	23·67	15·95	16·48	20·07	30·02
Queen's Town	..	..	..	..	..	..	..	..	22·05	28·34	24·85	24·36	21·22	14·57	21·58	21·88	23·48	22·86	12·66	16·70	16·22	..
Aliwal North	..	..	18·91	26·68	19·93	28·70	31·93	28·69	24·30	24·40	24·93	30·67	17·00	23·96	22·86	28·64	24·91	27·93	21·88	18·36	22·44	19·87
Kimberley	..	..	..	..	..	..	..	..	..	..	17·26	..	13·58	9·34	19·38	15·43	30·30	14·77	13·63	20·52	11·38	16·65
Natal.																						
Pietermaritzburg	31·08	30·27	31·49	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Gardens Cliffe	..	..	25·95	44·36	30·83	30·63	32·26	44·98	36·50	45·60	37·08	38·52	33·91	26·72	42·29	46·18	37·62	39·25	37·49	38·33	..	..
D'Urban	..	48·54	33·08	..	..	..	..	..	42·22	53·80	54·78	35·22	35·65	28·24	44·46	47·63	37·08	36·21	44·52	44·56	34·48	31·79
Ottawa	..	..	..	..	..	34·87	36·22	56·71	41·33	49·78	30·31	26·52	35·37	26·57	41·13	..	38·77	28·72	37·43	40·15	..	..

TABLE III.—AVERAGE PROPORTIONAL DEGREES OF YEARLY RAINFALL; ALSO OF THE YEARLY NUMBERS OF STATIONS POSSESSING RECORDS WITH 10 COMPLETE YEARS AND UPWARDS.

Year.	Rainfall.			No. of Stations.	Year.	Rainfall.			No. of Stations.	Year.	Rainfall.			No. of Stations.
	West.	East and Natal.	All Stations.			West.	East and Natal.	All Stations.			West.	East and Natal.	All Stations.	
1842	16·0	..	..	1	1857	14·0	17·0	14·8	4	1872	21·0	22·0	21·8	16
1843	15·0	..	..	1	1858	15·0	8·5	11·8	4	1873	14·0	11·0	11·5	17
1844	3·0	..	..	1	1859	26·0	8·0	20·0	3	1874	12·3	22·4	20·7	18
1845	7·0	..	..	1	1860	14·0	17·5	15·8	4	1875	9·3	19·0	17·6	21
1846	10·0	..	..	1	1861	12·0	7·0	9·0	5	1876	15·3	22·3	20·5	24
1847	10·0	..	..	1	1862	24·8	5·2	16·1	9	1877	22·0	6·3	10·2	20
1848	11·0	..	..	1	1863	18·0	22·4	20·4	9	1878	29·4	8·1	13·6	27
1849	14·0	..	..	1	1864	4·0	16·2	10·1	10	1879	6·5	16·5	14·3	28
1850	23·0	..	..	1	1865	4·6	6·6	5·6	10	1880	2·9	17·6	13·9	28
1851	10·5	11·5	11·0	4	1866	10·0	13·0	11·5	12	1881	11·9	16·2	15·2	29
1852	15·5	5·0	12·0	3	1867	9·7	14·4	12·6	16	1882	13·6	13·5	13·5	30
1853	12·5	..	12·5	2	1868	11·0	17·0	15·0	18	1883	20·4	8·6	11·8	30
1854	11·0	30·0	17·3	3	1869	20·5	12·0	15·0	17	1884	13·9	12·1	12·6	29
1855	17·5	24·0	21·4	5	1870	23·0	19·6	20·6	17	1885	14·5	12·6	13·2	28
1856	9·5	25·0	17·2	4	1871	10·0	14·2	13·0	17	1886	11·0	18·3	16·1	27

Mr. Gamble that the process is familiarly known as "Bloxamising," from the name of a meteorologist who employed a somewhat similar expedient.

The author is aware that others have previously drawn attention to the connection of meteorological observations recorded at the Royal Observatory of the Cape of Good Hope with the phenomena connected with sunspots. He has, however, thought it an interesting inquiry to test the matter by the methods now adopted.

The curves of average rainfall in the South-Western part of South Africa, and also those of the Royal Observatory itself, appear to vary with those of sunspot energy with considerable regularity from the year 1844 to about 1876. After this the curve of the rainfall for the extremely wet epoch of 1876-8 pursues an opposite course, other causes apparently then coming into play sufficiently powerful to mask any influence due to sunspot agency, and 1878, the minimum year of sunspot energy, became the maximum of rainfall.

The curves of rainfall for the Eastern and Natal divisions, or those for all stations, do not appear to offer any very marked coincidences with those of sunspots.

In all three rainfall diagrams there was a decided excess about 1856, which was also a year of minimum sunspot energy. After that in the curves for East and Natal, and all stations, there was not another decided maximum until the year 1876, which was also a period of depression of sunspot energy. This appears to indicate for East and Natal a major rainfall cycle of about twenty years.

As before pointed out, the Western maxima appear to occur somewhat later, viz. in 1859 and 1878.

The Author cannot conclude this paper without bearing testimony to the excellence of the climate of the Cape Colony, particularly in the highlands at some distance from the coast, where, owing to the dryness, there is an absence of the enervated feeling due to the moist heat often experienced elsewhere, and the climate is rendered most enjoyable and exhilarating, enabling exercise requiring great exertion to be taken, often even in the extreme heat.

TABLE IV.—WET AND DRY YEARS AT DIFFERENT GROUPS OF STATIONS FROM THE YEAR 1860 TO 1886.

1. *Main Divisions* (in Chronological Order).

Western Stations, inclined to wet, 1862, 1870, 1877, 1878.
" " dry, 1864, 1867, 1868, 1871, 1874, 1875, 1879, 1880, 1881, 1886.
" variable, but inclined to wet, 1869, 1883.
" " " dry, 1860, 1866, 1876, 1884.
Eastern and Natal Stations, both inclined to wet, 1874.
" " " dry, 1862, 1866, 1869, 1877, 1878, 1879, 1883, 1884.

2. *Sub-divisions of East and Natal.*

Natal Stations inclined to wet. East dry. 1868, 1880.
" " dry. " wet. 1860, 1867, 1870, 1871, 1875, 1876, 1881, 1886.

3. *Sub-divisions of East alone.*

South-western Stations inclined to wet, others drier, 1868, 1880, 1884, 1885, 1886.
" " " dry, " wetter, 1870, 1874, 1881.
South-eastern Stations inclined to wet, others drier, 1867, 1870, 1880, 1886.
" " " dry, " wetter, 1868, 1881.
North and North-eastern Stations inclined to wet, others drier, 1868, 1871, 1881.
" " " dry, " wetter, 1867.

4. *All Stations.*

All Stations inclined to wet, 1863, 1872.
" " dry, 1861, 1864, 1865, 1873, 1882, 1885.

5. *The Wettest Years* (in order of wetness).

In the West 1878, 1862, 1870, 1877.
" East 1876, 1874, 1870, 1872.
" Natal 1872, 1868, 1874, 1880.
All Stations 1872, 1874, 1870, 1876.

6. *The Driest Years* (in order of dryness).

In the West 1880, 1864, 1865, 1879.
" East 1862, 1877, 1865, 1883.
" Natal 1878, 1867, 1876, 1870.
All Stations 1865, 1864, 1877, 1866.

7. *Years with the greatest Contrast between West and East and Natal.*

Wettest in the West 1878, 1862, 1877, 1883.
" " East and Natal 1880, 1864, 1879, 1874.

8. *Year with the least contrast between West and East and Natal.*
1882, 1872, 1884, 1885.

TABLE V.—Coincidences between Monthly Rains in different parts South Africa.

1. Western Stations.

1. *Western Seasonable Autumn or Winter Rains similar to those at South-east Stations.*

1860	May, June.	1874	July.	1885	August.
1869	May.	1875	August.		
1873	June.	1876	May, June.	Total 7.	

2. *Western Autumn or Winter Rains similar to those at Eastern Stations.*

1866	April, May.	1871	July.	1880	August.
1867	May.	1872	May, July.	1881	May, August
1868	July.	1873	April.	1884	June.
1869	May.	1875	June.	1885	May. To

3. *Western Autumn or Winter Rains similar to those in Natal.*

1860	May.	1868	April, May.	1874	June (?).
1867	April.	1872	July.	1884	June.
		1873	April.		To

4. *Western Stations Rains varying much in Amount but not in Season.*

1883 All the Year.

2. Eastern Stations.

5. *Eastern Seasonable Summer Rains similar to those at Western Stations.*

1860	Jan. Feb. Mar.	1868	Jan. Feb. Mar.	1878	March.
1866	,, ,, ,,	1873	March.	1881	March.
1867	Feb. Mar.	1874	,,	1885	February.
		1875	Jan. Feb. Mar.		To

6. *Eastern Seasonable Spring Rains similar to those at Western Stations.*

1860	Oct. Nov.	1875	Nov. Dec.	1886	October.
1870	Oct.	1881	Nov.		To

3. Natal Stations.

7. *Natal Seasonable Summer Rains similar to those at Eastern Stations.*

1867	February.	1870	March.	1884	March.
1869	March.	1871	February.	1886	Feb.

8. *Natal Seasonable Spring Rains similar to those at Eastern Stations.*

1866	November.	1869	Oct. Nov. Dec.	1872	November.
1867	Oct. Nov.	1870	October.	1874	December.
1868	October.	1871	Oct. Nov. Dec.		

9. *Natal Seasonable Summer Rains similar to those in the West.*

1867	Jan. Feb. Mar.	1869	Jan. Feb. Mar.	1874	March.
1868	,, ,, ,,	1873	March.	1884	Feb.

10. *Natal Seasonable Spring Rains similar to those at Western Stations.*

1868	Oct. Nov. Dec.	1870	October.	1872	Nov.

4. Eastern and Natal Stations.

11. *Unseasonable Autumn and Winter Rains similar at Eastern and Natal*

1867	June, July, Sept.	1870	April.	1884	June.
1868	Aug. Sept. Oct.	1871	April, May, Sept.	1885	Sept.
1869	April, Aug.			1886	Apl July.

TABLE VI.—MONTHLY RAINFALL FOR THE VERY UNIFORMLY WET YEAR 1872.

Month.	Clanwilliam.		Royal Observatory.		Camfer's Kraal.		Graham's Town.		Aliwal North.		Merebank.	
	Very Wet.		High Mean.		Wet.		Very Wet.		Wet.		Wet.	
	1872.	Mean	1872.	Mean	1872.	Mean	1872.	Mean	1872.	Mean	1872.	Mean
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
January..	..	·12	·72	·67	1·16	·61	3·37	2·27	4·69	3·81	1·90	2·59
February	..	·23	·58	·61	·57	1·08	3·68	3·12	6·50	5·16	·76	5·32
March ..	·53	·34	1·39	·96	2·85	1·57	4·35	3·28	4·61	3·40	3·34	6·92
April	..	·51	·24	1·83	·59	·90	5·99	2·35	1·24	1·82	17·48	5·50
May	2·68	1·73	6·83	3·93	2·86	·74	8·04	1·97	2·42	1·21	3·57	1·27
June	1·34	1·51	4·64	4·42	·17	·33	3·65	1·13	·14	·63	3·86	1·05
July	3·12	1·74	2·39	3·46	·50	·26	2·07	1·64	·35	·56	4·21	1·07
August ..	2·52	1·01	7·68	3·34	·29	·38	2·18	2·15	·55	·44	·30	3·39
September	·45	·56	2·12	2·11	·18	·42	·24	2·45	·89	·74	3·90	2·14
Ootober ..	·21	·77	·94	1·58	..	·60	1·46	2·44	1·22	1·63	2·90	4·62
November	·35	·42	1·09	1·09	1·12	·86	3·35	3·23	4·26	2·72	7·06	5·46
December	·01	·27	.71	·81	·86	·71	1·27	2·76	1·82	2·56	3·11	4·87
Total	11·21	9·21	29·33	24·81	11·15	8·46	39·65	28·79	28·69	24·68	52·39	44·20

TABLE VII.—COMPARISON OF WOLF'S SUNSPOT NUMBERS WITH THE AVERAGE PROPORTIONAL DEGREES OF RAINFALL.

Year.	Wolf's Sunspot Numbers.	Rainfall.				Year.	Wolf's Sunspot Numbers.	Rainfall.				Year.	Wolf's Sunspot Numbers.	Rainfall.			
		Royal Observatory.	West.	East and Natal.	All Stations.			Royal Observatory.	West.	East and Natal.	All Stations.			Royal Observatory.	West.	East and Natal.	All Stations.
1844	15·0	11·3	..	..	..	1859	93·8	16·3	18·3	11·2	15·5	1874	44·6	16·0	15·8	18·4	18·0
1845	40·1	8·3	..	..	..	1860	95·7	19·7	18·3	11·3	15·9	1875	17·1	15·0	11·9	17·4	16·6
1846	61·5	6·7	..	..	..	1861	77·2	20·3	17·3	10·8	14·9	1876	11·3	16·3	12·3	21·2	19·6
1847	98·4	9·0	..	..	..	1862	59·1	19·0	16·9	9·9	13·6	1877	12·3	19·3	15·5	15·8	16·1
1848	124·3	10·3	..	..	..	1863	44·0	18·0	18·3	11·5	15·2	1878	3·4	24·0	22·2	12·2	14·8
1849	95·9	11·7	..	..	..	1864	46·9	13·7	15·6	14·6	15·5	1879	6·0	19·3	19·3	10·3	12·7
1850	66·5	16·0	..	..	..	1865	30·5	7·0	8·9	15·1	12·0	1880	32·3	11·3	12·9	14·1	13·9
1851	64·5	14·3	15·8	..	..	1866	16·3	2·7	6·2	11·9	9·0	1881	54·2	6·7	7·1	16·8	14·5
1852	54·2	13·3	16·3	..	..	1867	7·3	5·3	8·1	11·3	9·9	1882	59·7	12·0	9·5	15·7	14·2
1853	39·0	8·0	12·8	..	..	1868	37·3	6·3	10·2	14·8	13·3	1883	63·7	19·0	15·3	12·7	13·5
1854	20·6	7·7	13·0	..	..	1869	73·9	12·7	13·7	14·5	14·2	1884	63·4	19·7	16·0	11·4	12·6
1855	6·7	8·7	13·7	..	..	1870	139·1	15·0	18·2	16·2	16·9	1885	52·2	19·3	19·6	11·1	12·5
1856	4·3	7·7	16·0	26·3	18·6	1871	111·2	15·0	17·8	15·3	16·2	1886	..	18·3	13·1	14·6	14·1
1857	22·8	9·0	13·7	22·0	17·8	1872	101·7	14·0	18·0	18·6	18·5						
1858	54·8	9·0	12·8	16·8	14·6	1873	66·3	12·3	15·0	15·7	15·4						

DISCUSSION.

THE PRESIDENT (Dr. Marcet) said we were generally taught that mountain chains at no very great distance from the coast interrupted the passage of moisture from the sea, the rainfall being greater on the sea-side of the chain than on the land-side. He inquired if this was true of Cape Colony, and whether the flat extent of country in the centre of the peninsula was drier than the districts near the sea.

Mr. SYMONS considered Mr. Tripp's paper extremely useful as a summary of all the rainfall statistics for the Colony. He had seen in the Reports of the Meteorological Commission of the Cape of Good Hope some rather serious comments regarding some of the observations, the official inspector having found the rain-gauges at some stations in most unsatisfactory situations. If any of the values from these questionable sources had been quoted in the paper, it would be much better to omit them, and print only those which could be relied upon as correct. It was desirable that the height of the rain-gauges above the ground should also be stated. As regarded the method of classification adopted by Mr. Tripp for expressing the relative value of the rainfall in one year as compared with another, he rather thought this plan was inferior to the usual method of expressing the yearly fluctuations as ratios to the mean of the series. He (Mr. Symons) then instanced the rainfall recorded at Durban, which had a long break in the series, and explained how a mere arithmetical average was vitiated by the presence or absence of records for years of extreme rainfall, and how this evil was avoided by the method he preferred to use for such cases. So far as the relation between sunspots and rainfall was concerned the figures did seem to agree somewhat for a certain number of years, but then, as was so often the case, the connection appeared to break down entirely.

Mr. BLANFORD said there were many points of much interest in this paper, and there appeared to be some resemblance between certain features of the general distribution of the rainfall in Cape Colony and in India. He should like to have some information concerning the prevalence and direction of dry winds in the Colony, as he thought it very probable that a system of dry land winds did exist, and if so, a study of their relations to the rain-bearing winds might throw some light on the conditions that determined drought. There seemed to be nothing very regular in the succession of wet and dry years. The years 1876 and 1877 were very dry in India, while 1878 was on the whole the wettest year on record in that country. He noticed that a very similar state of things prevailed in Cape Colony. It was curious that the excessive rainfall in India in 1878 was due to the great fall over the Peninsula, Northern India being comparatively dry. The connection between sunspots and rainfall could hardly be decided from a study of these figures for Cape Colony. The registers of isolated stations and small areas were absolutely useless in evidence on such questions, owing to the magnitude of local irregularities. Of larger areas, India as a whole afforded no support to the hypothesis, and the only regions which so far seemed to favour the idea are the Carnatic, and in a minor degree perhaps Northern India, in respect of its winter rainfall. He thought it probable that in the course of a few years the registers now accumulating for the East Indian Archipelago, comprising Sumatra, Java, Borneo, &c., might afford valuable evidence on the question.

Mr. C. HARDING said that he fully endorsed Mr. Symons's remarks upon the labour and amount of work contained in this paper. With reference to Mr. Blanford's remarks as to the prevalence and direction of dry winds, he drew attention to a report on the gales experienced in the ocean district adjacent to the Cape of Good Hope, published by the Meteorological Office in 1882. The charts issued with this work showed that a Westerly wind prevailed in winter, or from April to October, while in summer the direction of the wind was Easterly. In drawing isobars on these charts it was found that the lines were much closer together in summer than in winter, and one was therefore driven to suppose that the force of the wind was greater in the summer months than during the winter. But this supposition was known to be contrary to the actual observations. In order to discover where the discrepancy occurred, the individual barometer readings were grouped according to their height; and it was then found that this disagreement was due to the fact that in the summer the range of the barometer

was very slight, while in the winter the range was much greater, the readings in the month of July varying from 29·0 ins. to 30·7 ins. He noticed that the year 1872 appeared to be the most uniformly wet in the whole of the series; it was remarkable that the same year was also the wettest recorded in England.

Mr. ARCHIBALD thought that in an analysis of observations of this character, the seasonal falls should be separated from those which were not seasonable. As regarded the connection between sunspots and the annual fluctuation of rainfall, it appeared that the falls in India in winter were in inverse ratio to the prevalence of sunspots. It was only from observations such as these in the Tropics and Sub-tropics that any connection could be sought after, and it certainly was an idle occupation to attempt to establish any relation between sunspots and the rainfall of such a country as England, where any secular seasonal variation was completely masked by the large irregular fluctuations due to other causes.

Mr. TRIPP, in reply to Dr. Marcet's question, said that the hills certainly did intercept the rainfall, for while on the Western Coast the rainfall was generally from 20 to 30 ins., in the interior it was only 5 to 10 ins. He had not adopted the method of ratios for all his calculations, because the method he had adopted afforded the simplest method of analysing a number of records, and ascertaining over what areas the rains extended. It was not easy to adopt the plan explained by Mr. Symons for filling up the gaps in a broken series of observations, such as those at the Cape Stations the stations being so far apart; and the rainfall and other climatic conditions varied greatly in different parts of the Colony. He had taken the ratios in many cases, and found that they varied to a considerable degree. He knew that several curious statements had been made regarding the position of some of the rain-gauges, but he did not believe that any of the records from these questionable sources were printed in the Reports of the Meteorological Commission, from which most of the figures contained in his paper were obtained. The majority of the rain-gauges were now placed at an elevation of 3 feet above the ground, and all the stations were regularly inspected by the Secretary. Concerning the rainfall in the year 1878, he said that it was the very wettest on record in the Cape Peninsula, but in most other parts of the Colony it was very deficient. He was unable to express any opinion upon the relation between the seasonal rains and the prevalence of sunspots; he might, however, observe that in most parts of South Africa, as in many other parts, the great majority of the rain fell at one season, although that season varied in different parts. He noted the very interesting remarks that fell from Mr. Blanford, from which it appeared that there was some similarity between the rainfall in some portions of the Cape and that of India. With reference to what Mr. Harding said as to the coincidence of the year 1872 being wet both here and at the Cape, he considered that there was also some similarity between the period of the last wet cycle at the Cape and that in the South, at any rate, of England.

SOME METHODS FOR CLOUD MEASUREMENTS.[1]

By NILS EKHOLM, of Upsala.

(Communicated by the Hon. Ralph Abercromby, F.R.Met.Soc.)

[Received November 14th, 1887—Read February 15th, 1888.]

Exact measurements of cloud positions afford, at present, almost the only easily available means of determining motions in the upper regions of the atmosphere. I think it will be of some interest for the Fellows of this Society if I lay before them a notice of some methods that seem to me likely to give the best results.

I. *Determination of the Direction and Angular Velocity of the Clouds.*

At the Swedish Polar Station, Cap Thordsen, in Spitzbergen (Smith's Observatory),[2] where the meteorological observations were under my guidance, we used the following simple apparatus for determining the direction and angular velocity of the clouds. At the top of a post 18 ft. high we fixed an eight-armed cross marking the cardinal points. An iron wire ring of 1 foot in diameter, horizontal and concentric with the middle point of the cross, connected the ends of the arms.

The observer, standing on the ground near the post, noticed the direction of the clouds relatively to the cross arms, thus determining exactly at least 16 points; then he counted the number of seconds (or of the beats of his watch) which elapsed while the cloud was seen to cross the ring.[3]

Assuming the ground around the post to be horizontal and the cloud to move on a horizontal and rectilinear trajectory with uniform velocity, the observer, wherever he places himself, will always find the same direction and the same number of seconds occupied by the transit as he would obtain if, standing vertically under the centre of the cross, he saw the cloud, moving at its actual elevation and with its actual velocity, crossing the ring, in passing through the zenith, in a direction parallel to that actually described.

In order to show that, let O be the observer's eye, A the centre of the ring, B a point on its circumference; and let us assume the observer sees the cloud passing from A to B, while it actually describes the trajectory CD. Draw through O and CD horizontal planes. They will meet the vertical drawn through A (the axis of the mast) in O′ and in C′ respectively. Join O′ with B and produce O′B so as to meet the plane CDC′ at a point D′; join D′ with C′.

From similar triangles we easily obtain

$$C'D' : AB = CD : AB ;$$

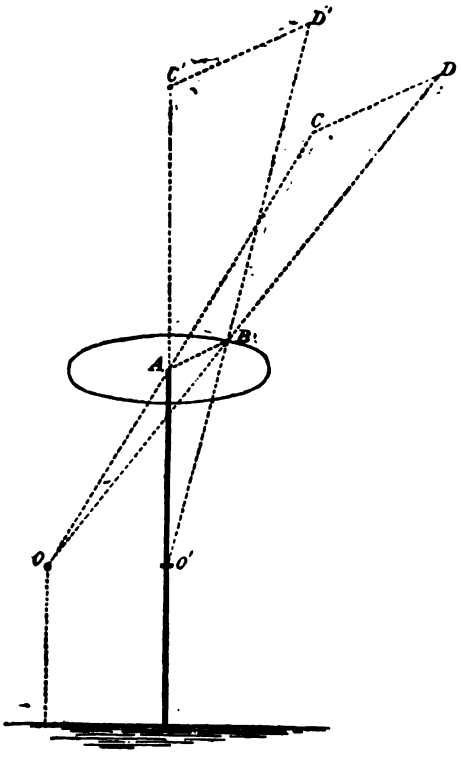
thus

$$C'D' = CD.$$

[1] Note.—This paper has also appeared in the *Meteorologische Zeitschrift* for April 1888.

[2] Lat. N. 78° 28′ 27″, Long. 15° 42·3 = 1h. 2m. 49s. E. from Greenwich.

[3] Obviously this apparatus is but a slight modification of the apparatus used for cloud observations by the Rev. W. Clement Ley, F.R.Met.Soc.



These two lines also are parallel, as being both parallel to AB. Hence the proposition immediately follows.

Suppose now the observed cloud point has a vertical component of velocity. This will actually be but very small compared with the horizontal one; hence it follows that the observer at O′ will still determine the horizontal component with a satisfactory approximation, as he will exactly determine the direction of the motion. But it is no longer so for the observer at O; generally he will neither observe the true component of the horizontal velocity nor the true direction. For this mode of observation it will, of course, be necessary to observe only clouds that pass not very far from the zenith. Those clouds offer, moreover, the advantage of having a greater apparent velocity than a cloud passing nearer the horizon. By means of this apparatus we observed in Spitzbergen about 1,500 cloud directions and 700 angular velocities of clouds. The time of a passage has varied between 2 seconds (" motion very fast ") and 250 seconds (" motion extremely slow "). At a very slow motion we ordinarily observed the passage through the half or quarter of the diameter of the ring. Naturally the observations would have been more convenient and exact if the cross had been provided with two or three concentric rings.

Let a be the angle AO'B (which once for all is determined by direct measurement or by calculation), let n be the observed number of seconds elapsed during the passage of the cloud. We can calculate the angular velocity of the cloud as it would be measured by an observer seeing it passing through his zenith. As a measure of this velocity we can use the radius of the circle as our unit, that is to say, the velocity can be expressed by the decimal fractions of the height of the cloud, described per second. For the sake of convenience, in order to avoid the decimals, we multiply the numbers thus obtained by 10,000; definitively then the velocity will be measured by the number of ten-thousandth parts of the height of the cloud described per second. Thus, if we know how to find the height of the cloud, we can obtain its absolute velocity by a simple multiplication.

Let v denote the angular velocity thus measured, V the absolute velocity in feet (or metres) per second, z the height of the cloud; we easily find

$$\frac{v}{10000} = \frac{2 \tan a}{n} \quad \ldots \quad \ldots \quad (1.)$$

$$V = \frac{vz}{10000} = \frac{2z \tan a}{n} \quad \ldots \quad (2.)$$

When the cloud floats at a height of 10,000 feet (or metres) v itself will represent the absolute velocity in feet (or metres) per second. Thus we may also say that v represents the velocity projected in a plane lying at a height of 10,000 feet (or metres).[1]

Exactly the same results as are obtained by means of the "nephoscope" now described are also given by the several mirror nephoscopes. The theory of those instruments is also essentially the same, and the formulæ (1) and (2) hold good for those instruments also. The rule of not observing the motion of a cloud far from zenith is equally applicable to them, and for the same reason. The cloud measurements determined at Upsala by Mr. Hagström and myself have shown, clouds often have a clearly marked vertical component of velocity.

Among the mirror nephoscopes, that constructed by Dr. Fineman at Upsala, and recommended by the International Meteorological Committee in Paris, 1885, has the advantage of being simple and convenient, and also of being easily adapted for use on board ship, if suspended as a marine compass. It has been described by the inventor in the *Rapport sur l'emploi du néphoscope* in the *Rapport au Comité météorologique international* by J. C. de Brito Capello and H. Hildebrand Hildebrandsson, Upsala, 1885.

Yet for cloud observations by land, and especially during an Arctic expedition, the simple apparatus used at Spitzbergen offers some advantages: they are—

[1] Dr. Vettin, in Berlin, has first introduced for v, thus defined, the name of "projected velocity," which seems to me to be very convenient: "Projicirte Geschwindigkeit der Wolken und deren Bestimmung, Von Dr. Vettin," in *Zeitschrift der Oesterr. Ges. für Meteorologie* XVIII. Band (1883), page 92. Dr. Vettin projects the velocity at a height of a German mile.

1st. The outlines of a badly marked cloud are more easily observed by direct vision than after reflection in a mirror.

2nd. The observation of the velocity is as simple as possible, as it requires nothing but the counting of a number of seconds; it will, in most cases, be the best to reckon the beats of the watch.

3rd. The apparatus is strong and simple, and not liable to derangement by bad weather, snow, rain, hoar frost, &c.

On the contrary, if a mirror is used, the position of the observer is more commodious; but for us who were charged with the duty of observing the whole sky, this advantage would have been of slight value.

Whichever apparatus is employed, I think it the best to reduce the observations by means of the formula (1), the object of the observations always being to give materials for calculating the absolute motion of the cloud. For that we need necessarily to determine the height of the cloud, either by direct measurement, or, at least approximately, by estimation. Then knowing this, and having calculated v from the observation (it will evidently be convenient to tabulate the formula (1) for the argument n), we obtain, according to the formula (2), the absolute velocity, as already remarked, by a simple multiplication.

II. *Direct Measurement of the Height and the absolute Motions of the Clouds.*

Such measurements were made at our Swedish Polar station in Spitzbergen in the year 1883, and have since been carried out at the Upsala Meteorological Observatory by Mr. Hagström and myself. The method of observation and calculation may be briefly described as follows:[1]—

The measurements are carried out by two observers placed at a convenient distance from each other, and communicating by means of a telephonic line. Each observer is provided with a simple altazimuth, carrying a tube without lenses, which can be directed in altitude and azimuth. The circles, horizontal and vertical, are divided in whole degrees; the verniers give every 10′, and we can estimate positions to 1′ (a finer vernier would be advantageous).[2]

The two observers, each provided with two telephones, one for hearing, the other for speaking, converse about the appearance of the clouds, until they agree on a point of cloud as well marked as possible; they determine beforehand the moment of observing, which they catch by counting the beats of their watches from a moment signalled by one of them by means of the telephone; then adjusting their instrument on the point agreed on, they note the exact time of observation, read the positions of the verniers, and describe

[1] It is fully described in the "Mesures des hauteurs et des mouvements des nuages, par N. Ekholm et K. L. Hagström (Présenté à la Société Royale des Sciences d' Upsal le 15 Novembre 1884), printed in the *Nova Acta*, Reg. Soc. Sc. Ups. Ser. III. 1885. Unfortunately the value of the base length there given is erroneous; it ought to be 489·5 m. instead of 420·7 m.

[2] We have found it advantageous to reduce the minutes to hundredths of degrees for the calculation; and we intend to divide the verniers so as to give directly 0°·1 instead of 10′. No doubt it would be most useful to have a complete decimal division.

shortly the appearance of the observed cloud, and of the sky generally, &c. (if possible, sketching also the outlines of the cloud). The observation being ended, they immediately observe again the same point of cloud, in order to determine its motion. This same operation is repeated, until the change of form of the cloud prevents it. But the change is often going on so rapidly that there is scarcely time for a single repetition, one observation occupying at least a minute. On other occasions we have succeeded in taking as many as ten measurements of the same point in pursuing it from one side of the sky to the other, but it is only the cirrus clouds that now and then are so persistent in form. These high clouds accordingly are the easiest to observe, while they are also the most interesting for scientific research.

Now for the calculation. Let T_1 and T_2 represent the positions of the alt-azimuths, b their horizontal and c their vertical distance. Take T_1 for origin, for axis of x a horizontal line drawn in the vertical plane passing through both instruments, for axis of y a horizontal line perpendicular to the former, and for axis of z the vertical line, the positive directions of the axis being reckoned towards T_2, towards the right hand of an observer placed in T_1 and regarding T_2, and towards the zenith respectively (thus the co-ordinates of T_2 will be $x = b$, $y = o$, $z = c$). Let h_1 and h_2 denote the angular heights, a_1 and a_2 the azimuths of the observed point measured respectively at T_1 and T_2 and corrected for the instrumental errors, the azimuths being reckoned from the positive axis of x with watch hands from 0° to 360°.

We wish to calculate the most probable co-ordinates of the observed point (say P).

If the observation were strictly correct, the vision lines directed on P would meet at that point. Suppose first it be so. We easily find

$$z = \frac{b \sin a_2 \tan h_1}{\sin (a_2 - a_1)} = c + \frac{b \sin a_1 \tan h_2}{\sin (a_2 - a_1)} \quad \ldots \quad \ldots \quad (3.)$$

from which

$$\sin a_1 \tan h_2 - \sin a_2 \tan h_1 = -\frac{c}{b} \sin (a_2 - a_1) \ldots \quad \ldots \quad (4.)$$

The equation (4) gives us the condition necessary and sufficient for the two vision lines meeting at P; thus it may serve for a preliminary control of the observation. But c being ordinarily very small as compared with b, it will suffice for the control to compare the values of the two terms of the first member of (4); if those terms differ somewhat from each other, the observers must have made some serious error, and the observation must be rejected.

Now supposing the observation to be good, but not strictly correct, for generally, the two lines of sight will not meet at P, though they will both pass very near that point. Then the two values of z given by (3) will not coincide, nor will their mean represent the most probable value of z. It is not so, as the mathematical analysis shows; we even think it impossible to calculate that value by means of (3). The same assertion holds good for the other co-ordinates. Thus other formulæ must be employed. For that purpose we

have admitted that the middle point of the shortest distance of the two vision lines represents the most probable position of the point aimed at. For of all possible points it is just the one being nearest to both those lines. Let us then calculate its co-ordinates.

Let P_1 and P_2 be the points at which the two lines meet, respectively, the line of their shortest distance; x_1, y_1, z_1, and x_2, y_2, z_2, the co-ordinates of those points, and x, y, z those of their middle point P; l_1, m_1, n_1 and l_2, m_2, n_2 the direction cosines of T_1P_1 and T_2P_2, and θ the angle between them. Also put

$$T_1P_1 = r_1,\ T_2P_2 = r_2,\ P_1P_2 = \Delta,$$

The following equations will serve to calculate the co-ordinates x, y, z sought:

$$\left.\begin{array}{l} l_1 = \cos h_1 \cos a_1,\quad l_2 = \cos h_2 \cos a_2 \\ m_1 = \cos h_1 \sin a_1,\quad m_2 = \cos h_2 \sin a_2 \\ n_1 = \sin h_1,\quad n_2 = \sin h_2 \end{array}\right\} \quad \ldots \quad \ldots \quad (5.)$$

$$\sin^2 \frac{\theta}{2} = \sin^2 \frac{h_1 - h_2}{2} + \cos h_1 \cos h_2 \sin^2 \frac{a_2 - a_1}{2} \quad \ldots \quad (6.)$$

$$\left.\begin{array}{l} \dfrac{r_1+r_2}{2} = \left\{\dfrac{b}{4}(l_1-l_2) + \dfrac{c}{4}(n_1-n_2)\right\} \operatorname{cosec}^2 \dfrac{\theta}{2} \\ \dfrac{r_1-r_2}{2} = \left\{\dfrac{b}{4}(l_1+l_2) + \dfrac{c}{4}(n_1+n_2)\right\} \sec^2 \dfrac{\theta}{2} \end{array}\right\} \quad \ldots \quad (7.)$$

$$\left.\begin{array}{lll} x_1 = l_1 r_1, & x_2 = l_2 r_2 + b, & x = \dfrac{x_1+x_2}{2} \\ y_1 = m_1 r_1, & y_2 = m_2 r_2 +, & y = \dfrac{y_1+y_2}{2} \\ z_1 = n_1 r_1, & z_2 = n_2 r_2 + c, & z = \dfrac{z_1+z_2}{2} \end{array}\right\} \quad \ldots \quad (8.)$$

Also the shortest distance is given by the formula

$$\Delta = \sqrt{(x_1-x_2)^2 + (y_1-y_2)^2 + (z_1-z_2)^2} \quad \ldots \quad \ldots \quad (9.)$$

This system seems a somewhat complicated one, but by using printed blank forms, logarithms of addition and subtraction, and a table giving directly log $\sin^2 \frac{a}{2}$ for the argument a, we reduce considerably the labour of numerical work. If the two instruments are exactly on the same level, then $c = o$, and the formulæ (7) are much simplified. If c, though not zero, is very little compared with b, then also the work can be much simplified by convenient arrangement, as we have shown in our paper. Thus calculating systematically a great number of observations (*e.g.* 100) at once, we have reduced to ten minutes the time necessary to calculate the co-ordinates of a single observation to within a metre. We think it worth while to maintain such a degree of minuteness, for then the value of Δ supplies an excellent measure of precision, a measure nearly indispensable, as the very nature of the phenomenon observed often introduces grievous errors even for the most practised observers.

In order to take the greatest possible advantage of that measure of precision, we have also endeavoured to calculate, by means of the value of Δ, the mean error of the co-ordinates, according to the method of least squares. As it would be too long to give those discussions here, I shall quote only the most important result obtained. If c is very small and θ not very great, then the mean error of z, the height of the cloud, will be given by the simple formula

$$m = \pm z \cot \theta \sqrt{E_0^2 + \left(\frac{\Delta}{2r}\right)^2} \quad \ldots \quad (10.)$$

where we have put $2r = r_1 + r_2$, and where E_0 represents the mean angular error purely instrumental, *i.e.* that which exists when looking at a perfectly distinct object, such as the sun. For the strict definition of E_0, I must refer to our paper. Moreover we have given formulæ for the calculation of the velocities, horizontal and vertical, of a cloud observed more than once. As these are easily deduced, I need not give them.

Lastly, a remark as to the method of observation. For the success of the observations the distance between the instruments must be neither too short nor too long. If the base be too short, the parallax θ obtained does not suffice to determine the position of the observed point in space. If too long, the observers are unable to recognise the same point of cloud, as perspective causes the cloud to present a very different appearance from the two stations (then the only means of succeeding is to take a cloud near the horizon).

We have therefore made the following proposition, read before the International Meteorological Committee in Paris 1885 : at each first-class Observatory there should be a system of three stations connected by telephonic lines, of which the one should be at a considerable distance from the other two (up to 5,000 metres say). This will give a base suitable for measurements on the highest clouds (cirrus). The other two stations should be at a distance of 500 to 1,000 metres,[1] a more suitable base for measurements of low level clouds. For the sake of a more complete control of the observations we might then, at pleasure, engage three observers measuring simultaneously the same clouds.

The number of measurements taken at Spitzbergen was about 50 ; those taken at Upsala by M. Hagström and myself amount to more than 2,000.[2] The longest base hitherto employed at Upsala is 1301·9 m. At the ends of this the instruments being invisible from the one to the other, we have determined the azimuth, as well as the length, by means of an exact triangu-

[1] "Rapport sur la méthode de mesurer les hauteurs et mouvements des nuages, par N. Ekholm et K. L. Hagström," in the *Rapport au Comité Météorologique International*, already referred to.

[2] In a few of them we were assisted by MM. J. Juhlin, Edv. Bergenström, and Aug. Falk, Cand. Phil. of the University, who from purely scientific interest offered themselves to help us.

lation, and afterwards controlled it by simultaneous solar observations. It was found to be exact up to one minute of arc.

This summer MM. Hagström and Falk have carried out about 400 cloud measurements at the Storlien railway station, in Jemtland (the Northern part of Sweden), making use there of two bases, the one for low level clouds about 700 metres in length, the other for middle and high level clouds about 2,400 metres. Thus they obtained very good determinations of the motion of the upper clouds.

DISCUSSION.

THE PRESIDENT (Dr. Marcet) remarked as to the effect of distance upon the apparent motion of objects within our range of vision, and said that clouds which were near to an observer appeared to move much quicker than those at a distance, just as objects seen from a railway train when close to us appear to move back very quickly, while those at a considerable distance look as if they travelled with us. He next explained by an illustration on the black board how he understood the author's method of measuring the altitude and speed of clouds.

Mr. DINES said that the instrument described in the first part of the paper had suggested to him what he thought would be a practical method of finding the height and velocity of clouds. Two observations of the angular velocity made at different altitudes would theoretically give the height and actual velocity, but as the absolute correctness of the observations could not be depended on, in practice the accuracy of the result would depend on the difference of altitude when compared with the height of the cloud. Still he thought that there must be many stations where a high tower or natural cliff would enable two observations to be made, and he was inclined to think that 100 feet difference of altitude would give a fairly good estimate for clouds under 4,000 feet high. If a greater difference of altitude could be obtained, the same method would give the height of the higher clouds. It would not be necessary to observe the same cloud at both places, but only the mean angular velocities.

Mr. SCOTT said that the great difficulty with the making of such cloud observations as Mr. Ekholm described in this country was to find men to do the work. At Upsala there was a large staff of professors and students in connection with the University available for the purpose of making observations. The staff at Kew Observatory were carrying on experiments in cloud measurement by means of photography, the two observers with their cameras being stationed 800 yards apart; but there was frequently a difficulty in finding two persons available for the purpose of making observations when the atmospheric conditions were favourable.

Mr. ABERCROMBY said that he had had the advantage of seeing some cloud measurements made by Mr. Ekholm at Upsala exactly in the manner described in the paper. In his opinion this altazimuth method was immeasurably better than the photographic system; in fact it was possible to take measurements of clouds by the former means which it would be absolutely impossible to obtain photographically. Prof. Hildebrandsson and the author had measured clouds with a refinement that had never before been attempted; for they not only got the height, horizontal velocity, and direction of translation, but even the rate of vertical rising or falling motion.

REPORT OF THE COUNCIL

FOR THE YEAR 1887.

"METEOROLOGICAL observations, to be of scientific value, must be made on an uniform plan, otherwise the results will not be mutually comparable. The Royal Meteorological Society insists on such uniformity, and accepts observations from those persons only who comply with its requirements, and whose instruments on inspection are found to be satisfactory both as regards their quality and situation."

The above words form the introductory paragraph of the second edition of the *Hints to Meteorological Observers*, prepared by the Society for the instruction and guidance of observers, especially of those who furnish the returns upon which the results in the *Meteorological Record* depend. They are also typical of the spirit in which all the work of the Society is carried out, and entail a considerable expenditure in the inspection of Stations and the preparation of the results for publication.

The work of the Society during the year has been carried on with the usual vigour, and the Council have received a large amount of assistance from their various Committees. To the official staff of the Society the Council are also indebted for zealous aid.

The Committees are constituted as follows:—

GENERAL PURPOSES COMMITTEE:—The President, Secretaries, Foreign Secretary, Treasurer, Mr. Abercromby, Mr. Baldwin Latham, Mr. Whipple, and Dr. Williams.

EDITING COMMITTEE:—The President, Mr. Inwards, and Mr. Scott.

ANNUAL EXHIBITION COMMITTEE:—The President, Secretaries, Dr. Marcet, Mr. Scott, Mr. Strachan, Capt. Toynbee, and Mr. Whipple.

EXPERIMENTAL RESEARCH COMMITTEE:—The President, Secretaries, Mr. Archibald, Mr. Benn, Mr. Eaton, Mr. C. Harding, Dr. Marcet, Mr. Russell, Mr. Scott, and Mr. Whipple.

DECREASE IN WATER SUPPLY COMMITTEE:—The President, Mr. Chatterton, Mr. Baldwin Latham, and Mr. Symons; with Mr. Scott, representing the Meteorological Council.

WIND FORCE COMMITTEE:—The President, Secretaries, Mr. Archibald, Mr. Chatterton, Mr. W. H. Dines, Mr. C. Harding, Mr. Laughton, Mr. Munro, Mr. Peek, Mr. Scott, Mr. Stanley, and Capt. Toynbee; with Mr. Whipple, representing the Kew Committee.

THUNDERSTORM COMMITTEE:—The President, Secretaries, Mr. Abercromby, Mr. Inwards, Mr. Scott, and Mr. Whipple.

The Council at their meeting of June 15th, adopted a loyal and dutiful Address to Her Majesty on the occasion of the completion of the fiftieth year of her reign. The Address was engrossed and illuminated on vellum, sealed with the seal of the Society, and presented to Her Majesty through the Home Secretary. A copy of the Address appears in the *Quarterly*

Journal, Vol. XIII. p. 313. A reply was subsequently received from the Home Secretary, stating "that Her Majesty was pleased to accept the same very graciously."

A cognate subject which came before the Council for consideration was the circular from Sir Frederick Abel, K.C.B., requesting, in the name of His Royal Highness the Prince of Wales, the assistance of the Society in procuring aid for the Imperial Institute, and setting out under twelve heads "what the Imperial Institute is to be." A circular in accordance with the request was sent to the Fellows; but the response was small, as most of those who intended to contribute had already done so in response to other requests.

Two matters of especial interest have engaged the attention of the Council during the year.

Firstly.—The Report of the Cloud Illustration Committee, to whom the question of illustrating Mr. Abercromby's paper on "Suggestions for an International Nomenclature of Clouds" was referred. After much consideration and inquiry as to cost and mode of printing, the Council selected ten of Mr. Abercromby's photographs which were most typical, which were reduced to half size, and printed on one plate by the Autotype Company. These were published in the April number of the *Quarterly Journal*, and appear to have given much satisfaction to the Fellows. The paper and illustrations have also been published separately.

Secondly.—In consequence of some papers having been received treating of the subject of lightning, one which perhaps has not received sufficient attention of late, it was decided to send a circular to the various Photographic Societies of England and to other bodies, asking their assistance in obtaining for the Society photographs of flashes of lightning; and also to advertise for photographs in the *British Journal of Photography* and in the *Photographic News*. This circular was issued in June, and met with cordial response; not only were many previously taken photographs sent, but also a large number were taken during the great storm of August 17th, 1887, and copies sent to the Society. About fifty-five photographs in all have been received.

The Council have also decided on taking up the systematic investigation of thunderstorms over the South-east of England, on a plan somewhat similar to that adopted in many other countries, Mr. Abercromby having obtained a grant of £25 from the Royal Society for the purpose of defraying expenses. Circulars and instructions will be sent to scientific and non-scientific observers, asking them to make certain definite observations on all thunderstorms that may occur in their neighbourhood, in order that a better knowledge may be acquired than we have hitherto possessed of the various phenomena preceding, accompanying and following thunderstorms.

The Council regret that they are unable to give any further information respecting the Helm Winds than they have already published, as, although the investigation is still proceeding, few occurrences of violent Helm Winds have been noticed. This is believed to have been due to the atmospheric

conditions, prevalent in the district during the year, not having been favourable to their production. Numerous slight Helm Winds have been noted, and the Council hope that when the opportunity occurs these observations will be fully discussed, as well as any observations of other instances of Helm Winds which may be brought under their notice.

The Council regret to report that the temperature observations on the Tower of Lincoln Cathedral have not been well kept during the year, and that some of the books containing the records have been lost. This is unfortunate, as the erection of the electrical thermometer on the Tower had entailed considerable expense and trouble. They, however, are glad to say that other arrangements, likely to prove more satisfactory, have been made for carrying on these observations in future.

Two new Climatological Stations have been started during the year, viz. Eastbourne and Southwell, whilst those at Alston, Cardiff, Teignmouth (Woodway), Tunbridge Wells, and Watford, have ceased to report.

An inspection of all the stations in the North of England has been made this year by the Assistant-Secretary, with fairly satisfactory results, the alterations in the errors of the instruments in use having been found to be less numerous than in former visits. Some of the stations were inspected for the first time, having been started since Mr. Marriott's previous visit to the North. It was found that at one station the thermometer screen was painted green, and the door opened to the south-west instead of to the north. This and other instances showing need of official inspection are mentioned in the report, which will be found in Appendix I. (p. 186). The inspection of the Lincoln station has led, as before intimated, to a change of the observer.

Reference was made in the opening paragraph to the new edition of *Hints to Observers*, which will, it is to be hoped, help all observers to carry on their work in accordance with the regulations of the Society. The new edition contains additional matter, and will be found an improvement on the first edition, which is out of print.

The Annual Exhibition of Instruments was very successful. It was held as usual in the Library of the Institution of Civil Engineers (by the kind permission of the Council), and the catalogue embraced 118 exhibits. Amongst them was a valuable collection of instruments and apparatus lately used on board the *Challenger* and at the Scottish Marine Station, in charge of Dr. Mill, who ably explained the peculiarities of construction of the various instruments, and their uses, not only at the meeting of the Society, but also in the Exhibition Room. Instruments were also received from the Meteorological Council, the Royal Meteorological Institute of the Netherlands, the Deutsche Seewarte, and the National Fish Culture Association (The Lochbuie Marine Institute), to all of whom the Council tendered their thanks. Numerous other exhibits were sent by private persons, and by our best known meteorological instrument makers, which greatly added to the interest of the Exhibition.

The *Quarterly Journal* has been published as usual (although the numbers have been a little after date), and has contained numerous interesting and

important contributions. One paper, with cloud illustrations, by Mr. Abercromby, has been already noticed; and others on the gales of October and December 1886, by Mr. C. Harding; the report on the Climatological Congress at Biarritz, by Mr. Symons; and on Phenological Observations, by the Rev. T. A. Preston; on variations in the quantity of Carbonic Acid in the Atmosphere, by Dr. Marcet and M. A. Landriset; and the Address of the President, may be especially mentioned. Four numbers of the *Meteorological Record* have appeared during the year, and (in accordance with the resolution of Council) the weather symbols hitherto published for each station have been omitted, these symbols not being considered to give information sufficiently important to justify the cost. It contains, with the Quarterly Reports on the Meteorology of England published by the Registrar-General, returns from above 100 meteorological stations, supplying altogether a valuable mass of information respecting the climate of our country.

The Meetings of the Society have as usual been held during the year in the Theatre of the Institution of Civil Engineers, kindly granted free of all expense to the Society. The Meetings have been well attended and the discussions good and well sustained; and the President has on several occasions had to close the discussions on papers in consequence of the length to which the meetings would otherwise have extended.

It should perhaps be mentioned that at a complimentary dinner to one of our Secretaries, Dr. J. W. Tripe, a valuable antique Silver Tea and Coffee Service was presented to him as an acknowledgment of nearly thirty years' work in connection with the Society.

Additions to a considerable extent have been made to the Library, both by presentation and purchase, a list of which will be found in Appendices III. and V. (pp. 144 and 149).

The office work of the Society has been carried on under unusual difficulties during this year, as the senior computer was ill and unable to attend to his duties for ten weeks, and the two junior computers left the service of the Society for other appointments. The latter have been replaced by two youths, who it is hoped will soon be so far trained as to act as efficient substitutes. This change will reduce the present expenditure without, it is hoped, diminishing the correctness of the results as published in the *Meteorological Record;* Mr. Marriott is using every effort to keep up the scientific quality of the work.

The number of Fellows is 2 less than last year. Twenty-five Fellows have been elected, while 8 have died, 15 have resigned, and 4 have been removed for default in the payment of their subscriptions. The number on the Roll is now 522, of whom 134 are Life Fellows and 18 Honorary Members.

The following table shows the changes that have occurred in the number of Fellows during the year:—

Fellows.	Annual.	Life.	Honorary.	Total.
1886, December 31 ...	373	133	18	524
Since elected	+24	+1	...	+25
Since compounded	− 1	+1	...	0
Deceased.....	− 7	−1	...	− 8
Retired	−15	...	..	−15
Defaulters	− 4	...	...	− 4
1887, December 31 ...	370	134	18	522

The Society has to deplore the loss by death of seven Fellows:—

Rev. Alexander Beverly, LL.D.	elected in the Society		Nov. 15, 1865.
The Right Hon. Earl Dalhousie, K.T.	,,	,,	Nov. 21, 1883.
George Dines	,,	,,	April 20, 1864.
William Henry Dunlop	,,	,,	Dec. 17, 1873.
Richard Ladd, F.R.A.S,, F.A.S.	,,	,,	Dec. 20, 1882.
Rev. Charles Pierrepoint Peach, M.A.	,,	,,	April 21, 1875.
Prof. Balfour Stewart, LL.D., F.R.S., F.R.A.S.		,,	June 18, 1862.
Marriott Ogle Tarbotton, M.Inst.C.E., F.G.S.		,,	June 16, 1869.

The income has been somewhat less than the expenditure in consequence of the subscriptions not having been paid this year so well as in former years. The balance at the commencement of 1887 was £247 17s. 10d., whilst on December 31st it was only £217 17s. 0d., showing a diminution of £30 0s. 10d.

Viewing the close connection of Meteorology with questions of Health, it seemed probable that many Officers of Health might be glad to join the Society; the Council resolved, therefore, to issue a circular to Medical Officers of Health, and to Medical Men at Health Resorts, describing briefly the work done and doing by the Society, and inviting them to become Fellows, which has already produced satisfactory results.

APPENDIX I.

REPORT ON THE INSPECTION OF STATIONS, 1887.

All the stations in the North of England have been visited, and were found to be generally in a very satisfactory condition. The alterations in the errors of the various instruments were less numerous than in former inspections. Several new stations have been started or changes of observers made since my last visit to the North. In all those cases where the observers have first communicated with me before commencing observations, I found their stations to be in accord with the requirements of the Royal

Meteorological Society; but at those places where the observers began in their own way, the instruments, &c., required some rearrangement. For instance, at Harrogate the thermometer screen, which was a home-made one, was painted green and so placed that the door opened to the South-west, instead of being painted white and with the door opening to the North. The new edition of the *Hints to Observers* with the illustrations will greatly help intending observers in the equipment of their stations, and if they carry out its recommendations they will have no difficulty in complying with the requirements of this Society.

At Oakamoor the rain-gauge had been so seriously damaged by a horse the day before my visit, that I considered it necessary to order a new one to be set up at once.

At Lincoln I found that at the time of my first visit the electrical thermometer was not working properly, as the cells of the battery were quite dry. On calling there again the second time I found the electrical thermometer agreed very closely with the check thermometer on the top of the tower. Mr. Mantle has had great difficulty in getting the readings taken by the school boys, and unfortunately two books containing the galvanometer readings have been lost. I have made some suggestions on the subject to Mr. Mantle which, if properly carried out, will obviate similar occurrences in the future.

Before I left town Mr. Benn informed me that the Penrith and District Literary and Scientific Society had decided to discontinue the payment of the observer at Cashwell Mine, on the eastern side of Cross Fell, as they considered that sufficient data had been collected from that station with regard to the Helm Wind investigation. Under these circumstances I thought it desirable to visit that station before the observations were discontinued, which I did on August 12th, and found it in a satisfactory condition.

WILLIAM MARRIOTT.

October 5th, 1887.

NOTES ON THE STATIONS.

BELPER, *August 23rd.*—The instruments were all in the same position as at the last inspection. The rain-gauge will be moved to a more open situation at the end of the year. All the thermometers were correct.

BLACKPOOL, *August 18th.*—The station at South Shore, which was in charge of the Rev. C. T. Ward, was discontinued at the end of June, from which time the observations have been carried on by Mr. J. Wolstenholme, Borough Surveyor, the instruments being placed in a garden near Christ Church, Queen Street, North Shore. The exposure is very good: but the rain-gauge required to be moved, as it was too near the thermometer screen. The sunshine recorder is placed on the roof of the Pavilion at the end of the Pier. A flag-staff is, however, occasionally placed in front of the instrument, which obstructs the sunshine between 2 and 3 p.m. Sea temperatures are also taken at the end of the Pier.

BOLTON, *August 19th.*—The instruments are placed in an octagonal enclosure in the Public Park, in a well exposed situation. Mr. Midgley was away at the time of my visit, but the attendant at the Chadwick Museum showed me the various instruments, which were generally in a satisfactory condition. The anemometer was placed at the corner of the refreshment pavilion, and was not fully exposed to all winds. It was recommended that the instrument be mounted on a pole in a more open situation.

BUXTON, *August 22nd.*—The thermometers were found to be correct. The grass minimum, however, does not work satisfactorily owing to the spirit evaporating frequently. The thermometer screen required painting. A Jordan sunshine recorder had been used in place of the Campbell instrument, since December 1886.

CASHWELL MINE, *August 12th.*—This station is on the east side of Cross Fell, 2,000 feet above sea-level, and was organised in connection with the Helm Wind inquiry. The thermometer screen and instruments were put up by Mr. Benn in February 1886, and were in charge of the foreman of the mine. The station was found to be in good order. Instructions were given for the observations to be discontinued, as the Penrith and District Literary and Scientific Society had decided to discontinue the payment of the observer.

CHEADLE, *August 20th.*—All the instruments were in good order. The zero of the maximum thermometer was found to have gone up 0°·2. The barometer has since the last inspection been cleaned and re-verified, and placed in a wooden frame with a glass door and window at each side.

CRAMLINGTON, *July 19th.*—The thermometers were found to be correct, but the muslin on the wet bulb was dirty, and the rain-gauge had been knocked about.

HARROGATE, *July 14th.*—The instruments are in a well exposed situation in the private grounds at West End Park. The thermometer screen, which is a home-made one, was painted green, and the door opened to the South-west. I recommended that the screen be moved so that the door should open to the North-west, and that it should be painted white; also, that the thermometers should be rearranged in the screen.

HODSOCK, *August 24th.*—This station was in good order. All the thermometers were correct except the earth thermometer, which had gone up 0°·3.

KIRKLAND, *August 13th.*—This station was organised in connection with the Helm Wind inquiry, the instruments being placed in position by Mr. Benn. The thermometers were found to be correct. The thermograph, which is in use, appeared to be a little sluggish.

LINCOLN, *July 13th.*—On examining the electrical thermometer it was found not to be in working order, the cells of the battery being quite dry. The thermometers in Mr. Mantle's garden were all correct, but the muslin on the wet bulb had not been changed for a considerable time. In conversation, it was found that the observations had not been entered up in the usual manner. They will for the future be entered up in the same way as at the other stations. Mr. Mantle has had great difficulty in getting the readings

of the electrical thermometer, which is at the Cathedral, taken by the school boys, and unfortunately two books containing the readings have been lost. Arrangements have been made by which a similar occurrence will be obviated for the future. On visiting this station again on August 26th, the electrical thermometer was found to be in good working order. The readings of the electrical and check thermometers agreed very closely. The other instruments were all in good condition.

MACCLESFIELD, *August 22nd.*—This station was in good order. On comparing the thermometers it was found that the wet bulb had gone up 0°·2.

NEWTON REIGNY, *August 11th.*—Everything at this station was in very good order.

OAKAMOOR, *August 20th.*—This station was in an unsatisfactory condition. The wet bulb was not working properly, and was, in fact, dry. The thermometer screen required painting. The rain-gauge had the day previous to my visit been kicked by a horse, and was all in pieces. I at once ordered a new rain-gauge, which was set up a few days after.

ROUNTON, *July 16th.*—This station was in good order. On comparing thermometers it was found that the zeros of the dry and wet had risen slightly.

SCALEBY, *August 11th.*—The wet bulb was not working properly. I altered the position of the thermometers in the screen, and put a cover over the water receptacle of the wet bulb. The rain-gauge required re-adjusting and fixing firmly in the ground.

SCARBOROUGH, *July 15th.*—Mr. A. Rowntree discontinued observing at the end of February, when the instruments were transferred to the care of Mr. W. Robinson, Westbourne Grove. They are placed in a garden with a moderately good exposure. The screen faces West-north-west. I recommended that the currant bushes in the garden should be kept away from the screen, and that some grass should be laid down. The screen required painting.

SEATHWAITE, *August 15th.*—This station was in good order. The index in the Phillip's maximum thermometer being too long, I took it with me to Keswick, and shortened the index by placing the instrument in a mixture of salt and ice. Mrs. Dixon, who for many years had been in charge of the station, left Seathwaite in May, when the observations were transferred to Mr. Douglas, the foreman of the Borrowdale Lead Mine.

SOUTHWELL, *August 25th.*—Mr. Edge removed his instruments from Strelley to Southwell in February. They are placed in the kitchen garden with a good exposure. The sunshine recorder is mounted on the roof of a stable. Two large trees on the East-north-east, which make an angle of above 12°, evidently intercept the sun's rays in the early morning. All the instruments were in good condition.

STAPLETON, *August 11th.*—When Dr. Stirling left Stapleton, the instruments were transferred to Dr. Lorraine. He had, however, unfortunately not received any instruction in the method of observing, and had consequently not complied with all the requirements of the Society. I explained the use of the various instruments, and put them all in working order.

USHAW, *July 18th.*—The instruments have all been arranged in accordance with the suggestions made at the last inspection. The thermometers were all correct. The screen required to be painted and also to be stayed to prevent vibration in strong winds.

WAKEFIELD, *August 24th.*—The thermometers were all correct. The wet bulb was not working properly, owing to a kind of cord being used for the conducting thread which did not conduct well. This I at once remedied by putting on fresh conducting cotton.

APPENDIX II.

OBITUARY NOTICES.

THE EARL OF DALHOUSIE was the eldest son of George Maule Ramsay, twelfth Earl, and was born in 1847. He was formerly in the Royal Navy, from which he retired in 1879, with the rank of Commander, after 18 years' service, the two last of which were passed in command of the *Britannia*.

In February, 1880, Lord Ramsay, then an undergraduate of Balliol College, contested a seat for Liverpool, but was unsuccessful. A few weeks later there was a general election, and Lord Ramsay was returned without a contest. His possession of a seat in the Lower House, however, was of very brief duration, for on July 20th his father died, and he was transferred to the House of Lords in succession to the peerage. In the following September he accepted office as a Lord-in-Waiting to the Queen during Mr. Gladstone's Administration.

It was while holding this office that Lord Dalhousie was largely instrumental in obtaining Her Majesty's permission for the Society to be called the "Royal Meteorological Society."

On the retirement of Sir George Trevelyan from the then recently created Secretaryship of State for Scotland, Lord Dalhousie accepted the office, and filled it till the resignation of Mr. Gladstone's Government.

Lord Dalhousie was deputy-lieutenant of St. Andrew's, and magistrate and deputy-lieutenant of Forfarshire, and sat in the House of Lords as Baron Ramsay in the peerage of the United Kingdom, which title was conferred upon his father in 1875.

He died at Havre on November 25th, 1887, the day after his wife's death.

MR. GEORGE DINES was born near Hitchen, in Hertfordshire, on June 15th, 1812. During all his earlier years, while associated with the late Mr. Thomas Cubitt, of Grosvenor Road, Pimlico, in his large business, and afterwards, while carrying on that business himself, he gave most of his leisure time to the investigation of meteorological questions, and after his retirement from business in 1876, he entered still more thoroughly into the study of these subjects, which he carried on with the keenest interest until

within a few weeks of his death, which occurred at his residence at Hersham, Walton-on-Thames, on May 25th, 1887.

He was elected a Fellow of the Royal Meteorological Society in 1864, and served on the Council from 1867 to 1874, being a Vice-President in 1873 and 1874. There were probably few meteorological questions in which he was not interested. In 1868 and 1869, he communicated papers on the connection between the Moon and the Rainfall, in which he clearly showed that the moon had no influence on the weather so far as rain is concerned. Speaking of the large number of figures upon which this paper was based, he used to say that he believed he had wasted more time upon that subject than any other person.

During 1869 and 1870, he made numerous experiments upon evaporation, the result of which he communicated to the Society in November 1870. These experiments caused him to doubt the accuracy of the tables by which the dew-point is obtained from the readings of the dry and wet bulb thermometers, and this led him to design the Hygrometer which is now known by his name, a description of which will be found in the *Quarterly Journal* for December 1879 (Vol. VI., p. 89). He considered, however, that the dry and wet bulb instruments gave most useful indications of the amount of moisture present in the air, although they could not be relied on to give the dew-point accurately in all circumstances, and that they could not be relied on at all when the temperature was below 32° Fahr.

The figures on which his disbelief in the moon's influence on weather was based were afterwards utilised by him to construct a Chart showing the Rainfall of the London District. In this the rainfall of every month from 1813 to 1872, the average of every day, and of every 5 day period, are shown graphically.

During the latter years of his life, while residing at Hersham, Mr. Dines spent much of his time in studying meteorological phenomena, and made numerous experiments on the following subjects:—The decrease of rainfall with elevation; the difference of temperature with elevation; the temperature of the dew-point; the pressure of the wind; and the formation of dew, mist, and fog; communicating papers on some of these subjects to the Royal Meteorological Society, and occasionally also to the British Association.

He was especially interested in all subjects relating to hygrometry, and made many experiments upon the weight of water in a given volume of air, whether in the form of vapour or of fog, the observations being made by drawing the air through sulphuric acid and then noting the increase of weight in the acid. He also observed the size of fog particles under the microscope, and was thus enabled to form an estimate of the number of such particles in a cubic foot of air. He stated the result of some of these experiments in the discussions on various papers published in the *Quarterly Journals*.

He was very incredulous about the high value of the wind pressures which are sometimes recorded, often saying that he did not believe such high pressures as 30 lbs. and 40 lbs. to the square foot would leave a single chimney in London standing. On this point his many experiments on the strength of

materials for engineering purposes, and his accurate knowledge in such matters, fully justified him in forming an opinion.

He was engaged upon experiments upon this subject shortly before his death.

Richard Ladd was born at Wandsworth on November 5th, 1848, and was educated at Dr. Semple's school at St. Margaret's, near Dover. He subsequently selected a seafaring life, and at the time of his death was navigating officer of the cable steam-ship *Minia*.

Extremely fond of astronomy and meteorology, he devoted most of his leisure to their study, and with the instruments lent him by the Meteorological Office he made many useful and excellent observations. He had always looked forward to the time when he could devote all his power and energy to astronomy, but this hope was frustrated by his untimely death on May 8rd, 1887.

Prof. Balfour Stewart, LL.D., F.R.S., was born on November 1st, 1828. He went to school at Dundee, but entered St. Andrew's University at the age of thirteen, and thence passed on to Edinburgh, where he studied under Prof. Forbes. Leaving college when he was eighteen years old, he was sent by his parents to serve his apprenticeship in business with a firm in Leith, and went out to Australia with a cousin, James Balfour, to start on a commercial career. But he was never fond of business, and soon returned home to Edinburgh, where he became assistant to Prof. Forbes in 1853. From 1855 to 1857 he was assistant to Mr. John Welsh at the Kew Observatory, returning there in 1859, when he was appointed Superintendent. He held this post until 1870, when he was appointed Professor of Physics at the Owens College, Manchester. He died of apoplexy on December 18th, 1887, at his residence, Ballymagarvey, near Drogheda, whither he had gone to spend the Christmas holidays.

Prof. Stewart's name was first prominently brought before the public by his researches on radiant heat. His paper was presented to the Royal Society of Edinburgh, and read on March 10th, 1858. It contains an account of experiments and arguments on the necessary relationship between the radiation and absorption of a substance. The whole science of spectrum analysis is founded on that relationship, and Prof. Stewart deserves a prominent place in the history of this branch of physics.

It is almost impossible now to realise the unsatisfactory and vague ideas which pervaded nearly all writings on the radiation of heat during the first half of this century. Prof. Stewart was the first to show that radiation was not a pure surface phenomenon, but that it was necessary to take account of the internal radiation of bodies. He proved that if a semi-transparent body is placed in an enclosure of uniform temperature, it must make up by its own radiation and reflection whatever heat it has absorbed from the enclosure. Kirchhoff shortly afterwards, and independently, treated the same subject, and it is interesting to compare the two memoirs. Prof. Stewart's reasoning is simpler, but it does not allow us to express the law in the definite and mathematical form in which it was published by Kirchhoff.

Prof. Stewart proved that the streams of radiant heat crossing any point of an enclosure are not altered by the interposition of a body, whether opaque or transparent. But the radiation crossing any point is made up of heat which has passed through different thicknesses of the transparent bodies and in various directions. What he established for the sum of these streams Kirchhoff proved for each individually. The reasoning thus becomes much more complicated, but the proof more complete. Prof. Stewart showed that the law must hold for each description of heat, that is to say, for the radiation of the different wave-lengths separately: it is this generalisation which forms the foundation of the theory of spectrum analysis.

From the time of his appointment to the Superintendence of the Kew Observatory until his death, Prof. Stewart's attention was principally given to the subject of cosmical physics. The connection between solar phenomena and meteorology fascinated him, and he spent much thought and labour in the investigation of this difficult and important subject. Broadly speaking, the facts are these:—Certain phenomena are observed on the sun to vary periodically. The regular terrestrial magnetic oscillations, as well as the irregular magnetic disturbances, show in their behaviour a marked correspondence with the state of the solar surface. No physical theory exists to account for the connection. Unless we admit the existence of some unknown force, the sun can only act on the earth either by gravitation (tidal action), by radiation, or by direct electric discharges. Considering that we have no evidence whatever as to the constancy of the sun's radiating power to within about 10 per cent., it seems only reasonable to try whether we can detect the same periodicities in meteorological and in solar phenomena.

Prof. Stewart paid attention especially to the shorter periods which have been detected or suspected in solar activity. The problem, in the absence of a well-defined physical theory, is one of very great difficulty, for it is almost impossible to decide in how far accidental regularities may mislead, and how far irregularities may hide effects which are admittedly small. Prof. Stewart was always cautious in his statements, and tried to verify his results by repeating his reductions whenever he had an opportunity of obtaining fresh material. His death is a great loss to the cause he had so much at heart, for much remains to be done, and there are few who are willing to undergo the great labour of computation with the risk of obtaining no definite result in the end. It is impossible to give in detail an account of all Prof. Stewart's investigations bearing on sun-spots, terrestrial magnetism, and meteorology, and it will be sufficient to mention the more important results which seem well established.

Employing both Carrington's observations and those made at Kew, he, in conjunction with Messrs. de la Rue and Loewy, investigated the size of sun-spots, as they passed over the solar disc, in relation to the position of the inner planets and Jupiter. It was found that the average size of spots attained its maximum on that side of the Sun which is turned away from Venus or from Mercury, and had its minimum opposite these planets. This behaviour is so decided with regard to Venus that the whole body of

observations could be split up into two parts, namely, Carrington's series and the Kew series, in each of which it is distinctly manifest.

The sun-spot period, with its average duration of about eleven years, shows very great irregularities both in the length and in the amplitude of the oscillation. Prof. Stewart has shown that from the year 1780 to 1870 the curve of solar activity can be best represented as a superposition of three oscillations, one of 10½, one of 12, and a minor one of about 16 years. The irregularities would thus be produced by the beats of these three fluctuations. As regards the connection between magnetical and meteorological phenomena, perhaps the most satisfactory results were obtained in his late researches conjointly with Mr. Lant Carpenter, in the connection between magnetic disturbances and the strength of the wind. A good case is made out for the conclusion that high and low disturbance values of magnetic force correspond with, and slightly precede, high and low wind values.

Prof. Stewart was the author of several text-books. His *Primer of Physics*, as well as his *Elements of Physics*, are well established as sound and clear elementary books. His book on *Heat* is an excellent treatise, and his Lesson in *Elementary Practical Physics*, written jointly with Mr. W. W. Haldane Gee, is the most complete exposition of experimental methods in Physics which has been written. He contributed to the International Scientific Series an admirable treatise on the Conservation of Energy. Prof. Stewart was also the author of the article "Terrestrial Magnetism" in the last edition of the *Encyclopædia Britannica*. The Royal Society Catalogue of Scientific Papers gives a list of 75 papers of which Prof. Stewart was either the sole or joint author. He was elected a Fellow of the Royal Society in 1862, and obtained the Rumford Medal in 1868. At the time of his death he was President of the Physical Society, and of the Manchester Literary and Philosophical Society. He was elected a Fellow of the Royal Meteorological Society on June 18th, 1862, and was a member of the Council in 1863 and 1864.

APPENDIX III.

LIST OF BOOKS PURCHASED.

ARMAND, DR.—Traité de Climatologie Générale du Globe. 8vo. (1873.)

ASTRO-METEOROLOGICAL SOCIETY.—Record, No. 3. 8vo. (1861.)

BARNES, DR. T.—On the average quantity of rain in Carlisle and the neighbourhood. 4to. (1870.)

BEARDMORE, N.—Hydraulic Tables. Second Edition. 8vo. (1852.)

BENNET, DR. J. H.—Mentone and the Riviera as a Winter Climate. 8vo. (1861.)

BRITISH ALMANAC for the year 1831. 12mo. (1830.)

————————, Companion to the, for 1831. 12mo. (1831.)

BUCHAN, A.—The Mean Pressure of the Atmosphere and the prevailing Winds over the Globe. Part II. 4to. (1869.)

CARENA, H.—Description d'un nouveau Baromètre pour les aëronautes. 4to. (1812.)

CARLINI, F.—Sulla legge delle variazioni orarie del barometro. 4to. (1828.)

CHAMBERS, G. F.—FitzRoy Weather Forecasts. 8vo.

CHRISTIE, J. R.—On the use of the Barometric Thermometer for the determination of relative heights. 4to. (1846.)

CLERK, LIEUT. H.—Meteorological Observations made on board Her Majesty's (hired) Bark "Pagoda," Jan. 10th to June 20th, 1845. 4to. (1846.)

CRAHAY, PROF. J. G.—Mémoire sur la Météorologie. 4to. (1837.)

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APPENDIX VI.

REPORTS OF OBSERVATORIES, &c.

THE METEOROLOGICAL OFFICE.—Lieut.-Gen. R. Strachey, R.E., C.S.I., F.R.S., Chairman of Council; Robert H. Scott, M.A., F.R.S., Secretary; Captain H. Toynbee, F.R.A.S., Marine Superintendent; Nav. Lieut. C. W. Baillie, F.R.A.S., Assistant do.

The only change which has taken place in the administration of the office has been the resignation by Prof. Stokes, President of the Royal Society, of his seat on the Council in consequence of his election to the House of Commons. The vacancy thus caused has been filled by the nomination of Mr. Alex. Buchan, F.R.S.E., as representative of Scotland on the Council.

Marine Meteorology.—The investigation into the weather of the North Atlantic for the thirteen months ending with August 1883, which has mainly occupied this branch of the office for the past four years, has now been completed, and the concluding part of the charts will shortly be published. One of the Foreign Members of this Society, Prof. Elias Loomis, who has devoted much attention to Atlantic weather, has expressed himself in the following gratifying language:—"I have recently been studying the Atlantic charts, and have been able to extract from them important information respecting rainfall, such as I have not been able to obtain from any other Atlantic charts which I have seen."

The office has, at the suggestion of Dr. Meldrum, undertaken the discussion of the Aden cyclone of June 2nd, 1885, and is preparing daily synoptic charts of the North Indian Ocean and Red Sea for the period of six weeks from May 15th to June 25th, so as to embrace not only the particular storm above mentioned, but some others which occurred at about the same date. This is the first attempt which has been made to draw synoptic charts of this part of the globe, and though the deficiency of land observations from Abyssinia and Arabia renders the isobars fragmentary, it is hoped that the results obtained will be interesting and instructive.

The Cyclone Tracks of the Indian Ocean.—The Meteorological Society of the Mauritius has, as is well known, devoted much attention to this subject, and Dr. Meldrum has laid some results of its work before the British Association. The office has undertaken to publish Dr. Meldrum's storm-tracks for the period of forty years from 1848 on twelve monthly charts, and the work of preparation of these charts has been set on foot.

The Meteorology of the Red Sea.—This inquiry has been actively pursued, and monthly charts are being prepared. Information to supplement that existing in the office has been obtained from the Admiralty, the Peninsular and Oriental Company, and the Royal Meteorological Institute of the Netherlands.

The Charts of Barometrical Pressure for all Oceans for the four months of February, May, August, and November, are now completed, and will appear in a brief space of time.

The Currents of the Ocean.—The office has undertaken the preparation of monthly current charts for all oceans. This is a perfectly novel inquiry, for it is only for a few districts that monthly current charts have been drawn, as by Fergusson for the Arabian Gulf. The published charts, for the most part, only give the mean current for the year, and it may therefore be anticipated that the present inquiry, which will be a protracted one, will throw some light on oceanic circulation.

Weather Telegraphy.—There has been no material change in the operations of this department during the year. The service of telegrams from the United States has not been found as useful as it had been hoped it would have proved, and it is possible that this may be suppressed, its value not justifying its cost.

The Weekly Weather Report.—At the commencement of the year six new Scottish Stations were added to the list of those included in the Report. It is hoped that this addition will render the information for Scotland much more complete than heretofore.

New columns were also added to the summary on the first page, showing for accumulated heat the differences from the average for each week. The volume for 1887 contained an additional appendix, giving the mean temperature of each week, for each of the eleven districts, on the average of eight years, nine years, and ten years separately, commencing with 1878.

The issue of the *Monthly Weather Report* for 1887 has been delayed, from pressure of work. The arrears will, it is hoped, be speedily recovered.

The Land Meteorology of the British Islands.—The *Quarterly Weather Report* for 1878 has been completed, and two parts of that for 1879 have appeared. Much of the time of this branch of the office has been taken up with the preparation of a part of the Report on the Krakatoa eruption, which has involved the careful revision of the proof of the entire Report: a very protracted inquiry.

The *Hourly Readings* are published up to July 1885. The treatment of the twelve-years barograms for the seven observatories by means of the Harmonic Analyser has been continued, and the results for eight years are nearly complete.

The volume of *Observations at the Stations of the Second Order* for 1883 has appeared, and that for 1884 is in hand.

A very interesting inquiry has occupied part of the time of the staff during the year, viz. the discussion of all the returns from the stations maintained from the year 1852 to the present date, first, by the Royal Engineers, and latterly by the Army Medical Department. These returns contain a large amount of climatological information for Foreign and Colonial Stations, and such of the results as appear to be trustworthy will be published.—*March 15th*, 1888.

ROYAL OBSERVATORY, GREENWICH.—W. H. M. Christie, M.A., F.R.S., Astronomer Royal.—During the year 1887 no change of importance has taken place either in the instruments of the Magnetical and Meteorological Department of the Observatory, or in the methods of reduction employed.

The observations of temperature of the air on the roof of the Magnet House (commenced in 1886), and the observations in a Stevenson screen on the ground (commenced in 1887), are still continued. The maximum reading on the roof of the Magnet House, 20 feet above the ground, is generally lower than that on the ordinary stand, 4 feet above the ground, and the minimum reading generally higher. On the average of the year 1886, the maximum reading was lower by 0°·7, and the minimum reading higher by 0°·7. The observations of the year 1887 and the Stevenson screen observations have not yet been discussed.

Some difficulties having been experienced through defects in the driving clock of the new thermograph, it became necessary to partially reconstruct it. During the interruption thereby caused, the old thermograph was again employed. Registration with the new apparatus was recommenced in October last, since which time its action has been in every way satisfactory.

Since the beginning of the year 1888 two sheets have been placed daily on each cylinder, giving thereby a duplicate register of barometer, dry and wet bulb thermometers and electrometer.

Considerable progress has been made with the reduction of the photographic records of the barometer from 1874 to 1876, and of the dry and wet bulb thermometers from 1869 to 1876. When done, this work will complete the reduction of the barometric records from 1854, and of the dry and wet thermometer records from 1849 to the present time.—*March 3rd*, 1888.

ROYAL OBSERVATORY, EDINBURGH.—Prof. C. Piazzi Smyth, F.R.S.E., Astronomer Royal for Scotland.—The bi-diurnal observations at fifty-five stations of the Scottish Meteorological Society have been computed at this Observatory for the purposes of the Registrar-General of Births, Deaths, &c. in Scotland, and have been published in that officer's monthly and quarterly returns.

The Astronomer has also been preparing thirty-one *chronological* Tables of Mean Scottish Meteorology for the months in every year from 1856 to 1887 inclusive.

Their origin took place in the following manner:—

When the Astronomer was called on by Government in 1858 to begin the above meteorological calculations for the Registrar-General of Scotland, he found no difficulty in applying the ordinary instrumental corrections, and exhibiting monthly means collected from the bi-diurnal observations, first for each station by itself, and then for the mean of all the stations, as representing fairly the grand geographical mean for the whole country, from month to month.

But there was still no opportunity of ascertaining for any month in any one year how far the season might be an extraordinary one in any or all the usual meteorological returns. The historical element as to annual recurrences, agreements or disagreements, was then, in fact, entirely wanting, and could only be supplied by continuous observation and registration, such as is suitable and usual in Government Observatories. To supply this want, therefore, the Astronomer specially applied himself, and entered each month's means for the whole country in ledgers as the years went by, one under the other, so that means might easily be taken for every successive annual accumulation of years from the beginning of the activities of the Scottish Meteorological Society down to the latest passing period.

At first, from the frequently very great differences of the months of one year from those of another, these chronological means used to vary rather violently in adjacent years; but the differences were always decreasing, so that after sixteen years had gone by, or in 1871, he thought it useful for the public to print all those returns in the 13th vol. of the *Edinburgh Astronomical Observations*, as a contribution to the successive time-features of the climate of Scotland, as referred to one central mean point of space for the whole country.

Sixteen more years have now been tabulated, and the final results are for thirty-two years, and give us great, though still not perfect, assurance of the limits of the surprises which Nature may have in store for the nation.

On this occasion of printing, however, besides the twenty-one tables of which the old series consisted, taking up all the more ordinary and orthodox meteorological points, he has added ten new tables to represent the answers of observation to new requirements of scientific theory, and records with pleasure that while the chief labour and merit of preparing the twenty-one old tables up to the year 1880, were mainly due to the late Mr. Alexander Wallace, M.A., then first Assistant Astronomer in the Royal Observatory, the same merit is now due to Mr. Thomas Heath, B.A., for continuing the old tables from 1880 to the present year, and preparing the new tables for the whole period from 1856 to 1887.

The Astronomer has further commenced an idea of exhibiting in tabular form the local excesses of meteorological returns for single stations of the Scottish Meteorological Society in single years, in order to compare one part of the country safely against another; and while he has finished the MSS. for Vol. XVI. of the *Edinburgh Observations*, and is applying to Government for leave to print it, he may mention to the Royal Meteorological Society that amongst other Spectroscopic Memoirs therein there is a pretty full one on the Meteorology of the Rain-band.—*December 24th*, 1887.

THE KEW OBSERVATORY OF THE ROYAL SOCIETY, RICHMOND, SURREY.—

G. M. Whipple, B.Sc., F.R.A.S., Superintendent.—The several self-recording instruments for the continuous registration respectively of atmospheric pressure, temperature and humidity, wind (direction and velocity), bright sunshine and rain, have been maintained in regular operation throughout the year. The standard eye observations for the control of the automatic records have been duly registered during the year, together with the daily observations in connection with the U. S. Signal Service synchronous system.

The standard barometer (Adie 655) was fixed in the magnetograph room adjacent to the barograph, and read five times daily at observation hours, in order to compare its indications with those of the standard barometer in another part of the building. Readings were continually made from January 1st to July last, and are now under discussion.

Turf has been laid down under the screen of the thermograph with a view to avoiding effects of radiation as much as possible.

The new quadrant electrometer, constructed on Mr. de la Rue's principle, with Professor Clifton's improvements, together with a chloride of silver battery of 60 cells, for the purpose of maintaining the potential of the quadrants at a certain point, gave great satisfaction during the year, and was found to be a marked improvement upon the older form of the instrument. On September 2nd, during a high wind, a part of the instrument was accidentally set on fire by the gas burner, and the apparatus narrowly escaped destruction.

The cameras used in cloud photography having been put in order, and had new adjustable rapid shutters fitted, were again brought into use, and by request of the Meteorological Council twenty-four sets of photographs comprising ninety negatives were taken on fourteen days; chief attention was directed to the photographing of high cirrus clouds. Prints of all the pictures have been made on cyanotype paper, which, together with the observational data, have been transferred to the Meteorological Office for the reduction and computation of cloud heights and velocities, Professor Stokes's cloud projection apparatus having also been transferred there for the purpose.

The observations of the black bulb thermometers *in vacuo* made during 1886 were reduced and discussed, and the results found to be no more satisfactory than those obtained in previous years, the *vacua* in all of the instruments having deteriorated, and their readings having become lowered during the time they were under observation, whilst the readings differed considerably amongst themselves. Mr. de la Rue having undertaken to submit the tubes to a lengthy exhaustion, three instruments were fitted with new jackets and sealed on to the air pump in his laboratory. They were there exhausted almost daily, the atmospheric pressure being reduced and maintained at about 0·06 M from April to the end of September. On October 1st they were removed from the laboratory and replaced on the stand at the Observatory, having been read daily ever since. Large differences are still found to exist in the readings of the similar and similarly placed instruments.

The Committee have had their attention called to the fact that several scales are in use for graduating the scales of heights upon the dials of aneroids. Upon consideration the Committee recommend as desirable the employment of Sir G. B. Airy's scale, published in 1867, and its corresponding equivalent metric scale in all cases where possible.

Two highly sensitive aneroids with Bourdon tubes substituted for the ordinary corrugated vacuum boxes, constructed by MM. Richard Frères, of Paris, have been examined for constancy at the request of the Meteorological Council. It was found, however, that the metal of the tubes underwent changes similar to those experienced by the usual aneroid boxes, and the instruments were, therefore, liable to the same errors as the common aneroid.

A Beckley Rain Gauge was obtained, fitted with a Stonyhurst discharger, and, after due trial, sent to the Mauritius Observatory, where an opportunity will be afforded of noting the behaviour of the improved instrument during tropical rains.

Dr. Doberck, the Director of the Hong Kong Observatory, having obtained a Royal Society grant for the purpose of re-calculating Hygrometric tables, Mr. Whipple procured and forwarded to him examples of Alluard's, Crova's, and Dines' instruments, after making preliminary observations with them at Kew.

Mr. G. J. Symons, F.R.S., having received a grant from the Government Grant

Fund of the Royal Society, for the purpose of investigating the temperatures of certain hot springs in the South of France and the Pyrenees, had a number of specially prepared thermometers carefully verified at the Observatory, both before and after he had made use of them abroad.

Mr. Whipple has recently designed two new simple forms of maximum pressure anemometers, which he exhibited before the Royal Meteorological Society, and described in a paper read on April 20th. They were also shown at the Exhibition of the Royal Cornwall Polytechnic Society at Falmouth in September.

The Stevenson screen fixed on the lawn was blown over during the gale of September 2nd last, but fortunately the injury done by the accident was very trivial, as the screen was not in use at the time.

In the verification department nearly 14,000 instruments belonging to one or the other of twenty-seven different classes have undergone examination, and in the rating branch of the Observatory some 510 watches and 27 marine chronometers have been submitted to the specified tests.—*February 15th*, 1888.

RADCLIFFE OBSERVATORY, OXFORD.—E. J. Stone, M.A., F.R.S., Radcliffe Observer.—The meteorological observations have been regularly made on the same plan and with the same instruments as last year.

The self-recording instruments have been in satisfactory operation. Readings of the standard instruments are frequently taken during each day, and sometimes through the night, for check of the scale of the photographic curves.

Early in the year the zero-point of all the thermometers was carefully tested in melting ice, and, with the exception of the minimum on grass, showed but slight, if any change.

The Daily Weather Report and the evening forecast of the Meteorological Office, together with the readings of our instruments, are daily exhibited at the outer gates of the Observatory for the information of the public.

The eye-observations are reduced to the end of 1887. The *Meteorological Results* for 1884 have been printed, and were distributed last September. Those for 1885 are in course of preparation for the printer. The photographic curves for 1886 are now under measurement; the rain-gauge curves are measured to the end of 1887, and the sunshine cards to date.

Weather Reports have been sent, as in previous years, daily (by telegram) to the Meteorological Office; bi-monthly to the U. S. Signal Office; monthly to the Registrar-General and the local newspapers; and yearly to Symons's *British Rainfall*, and to others by request.

The mean reading of the barometer was above the average for each month until October (inclusive); the temperature of the air was below the average of the last thirty-two years from January to May and September to December; the mean of the year 1887 (47°·6) was below the average by 1°·6. The maximum reached 85°·3 on July 3rd, 84°·2 on July 4th, and 84°·1 on August 6th. The minimum was 14°·0 on January 1st, and except during the month of February, the weather until near the end of May was generally cold, dull, with frequent snow, fog and sharp frosts; but from June 6th to August 30th it was warm, bright, and exceptionally dry, rain falling only on eleven days during this period; the amount of bright sunshine was 1,580 hours for the year; the amount recorded for the three months, June, July and August, was 753 hours. Very little strong wind occurred after April 6th; thunderstorms occurred on only five days, and were very light, except that on August 17th; the rainfall was below the average for each month except January and March, it fell on only 115 days to the amount of 19·392 ins., or 7·192 ins. below the average: heavy snow fell on January 3rd-4th, and March 14th-15th (10 inches deep). Zodiacal light was very bright on March 12th. A series of solar halos and mock-suns was observed on February 4th.—*January 31st*, 1888.

STONYHURST COLLEGE OBSERVATORY.—Rev. S. J. Perry, F.R.S.—All the self-recording and other meteorological instruments have been in active operation as in former years. The Registers for the ten-year period 1876 to 1885 have been

sent by request to the Medical Officer of the Local Board of Health, Somerset House, for comparison with other records. A series of readings of the Kew and Stonyhurst Declination Magnetograms have been tabulated to furnish materials for a continuation of the comparison published in the *Proceedings of the Royal Society* by the late Dr. B. Stewart and the Rev. S. J. Perry.—*January 9th*, 1888.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

JANUARY 18TH, 1888.

Ordinary Meeting.

WILLIAM ELLIS, F.R.A.S., President, in the Chair.

CHARLES HARRISON BLACKLEY, M.D., Arnside House, Old Trafford, Manchester;
HENRY EDWARD BRAMELD, L.R.C.P., Saltburn-by-the-Sea;
ERIC HENRY STUART BRUCE, M.A., Wilton House, Pitt Street, Kensington, W.;
WILLIAM FORREST, 13 Hesketh Street, Southport;
JOSEPH GROVES, B.A., M.D., F.G.S., Carisbrooke, Isle of Wight;
CHARLES HARRISON, M.D., 30 Newland, Lincoln;
GEORGE COOPER HARRISON, L.R.C.P., The Grange, York Road, Southport;
NARCIS RICHARD HASWELL, M.R.C.S., Helston;
ROBERT LAING, L.R.C.P., M.R.C.S., 29 Waterloo Road, Blyth;
HUGH JAMES LLOYD, L.R.C.P., J.P., Ty'nycoed, Barmouth;
HENRY THOMAS HARVEY MEAD, M.R.C.S., Christchurch;
CHARLES PERKS, L.R.C.P., M.R.C.S., 181 High Street, Burton-on-Trent;
WILLIAM ROYSTON PIKE, M.R.C.S., Yarborough Villa, Elm Grove, Southsea;
JOHN LATHAM RUSHTON, M.D., East View, Macclesfield; and
JOHN HARRISON WALKER, L.R.C.P., M.R.C.S., Pickering,
were balloted for and duly elected Fellows of the Society.

The following Paper was read:—

"THE NON-INSTRUMENTAL METEOROLOGY OF ENGLAND, WALES, AND IRELAND." By G. M. WHIPPLE, B.Sc., F.R.Met.Soc., F.R.A.S. (p. 92.)

JANUARY 18TH, 1888.

Annual General Meeting.

WILLIAM ELLIS, F.R.A.S., President, in the Chair.

Mr. H. HARRIES and Mr. M. JACKSON were appointed Scrutineers of the Ballot for Officers and Council.

Dr. TRIPE read the Report of the Council and the Balance Sheet for the past year. (p. 132.)

It was proposed by the PRESIDENT, seconded by Dr. TRIPE, and resolved:—"That the Report of the Council be received and adopted, and printed in the *Quarterly Journal* of the Society."

It was proposed by Mr. BEAUFORT, seconded by Mr. BAYARD, and resolved:—"That the best thanks of the Royal Meteorological Society be communicated to

the Council of the Institution of Civil Engineers for having granted the Society free permission to hold its Meetings in the rooms of the Institution."

It was proposed by Capt. TONYBEE, seconded by Mr. DYASON, and resolved:— "That the thanks of the Society be given to the Officers and other Members of the Council for their services during the past year."

It was proposed by Mr. STOKES, seconded by Mr. EDMONDS, and resolved:— "That the thanks of the Society be given to the Standing Committees, and to the Auditors, and that the Committees be requested to continue their duties till the next Council Meeting."

The PRESIDENT (Mr. Ellis) then delivered his Address. (The publication of this Address is deferred.)

It was proposed by Dr. MARCET, seconded by Mr. LATHAM, and resolved:— "That the thanks of the Society be given to the President for the ability and courtesy displayed by him in the Chair during the past year, and for his Address, and that he be requested to allow it to be printed in the *Quarterly Journal* of the Society."

The Scrutineers declared the following gentlemen to be the Officers and Council for the ensuing year, viz.:—

President.

WILLIAM MARCET, M.D., F.R.S., F.C.S.

Vice-Presidents.

FRANCIS CAMPBELL BAYARD, LL.M.
WILLIAM ELLIS, F.R.A.S.
CHARLES HARDING.
RICHARD INWARDS, F.R.A.S.

Treasurer.

HENRY PERIGAL, F.R.A.S., F.R.M.S.

Trustees.

HON. FRANCIS ALBERT ROLLO RUSSELL, M.A.
STEPHEN WILLIAM SILVER, F.R.G.S.

Secretaries.

GEORGE JAMES SYMONS, F.R.S.
JOHN WILLIAM TRIPE, M.D., M.R.C.P.ED.

Foreign Secretary.

ROBERT HENRY SCOTT, M.A., F.R.S., F.G.S.

Council.

HON. RALPH ABERCROMBY.
ROBERT ANDREW ALLISON, M.P.
EDMUND DOUGLAS ARCHIBALD, M.A.
WILLIAM MORRIS BEAUFORT, F.R.A.S., F.R.G.S.
HENRY FRANCIS BLANFORD, F.R.S., F.G.S.
ARTHUR BREWIN.
GEORGE CHATTERTON, M.A., M.Inst.C.E.
WILLIAM HENRY DINES, B.A.
HENRY STORKS EATON, M.A.
BALDWIN LATHAM, M.Inst.C.E., F.G.S.
EDWARD MAWLEY, F.R.H.S.
CHARLES THEODORE WILLIAMS, M.A., M.D., F.R.C.P.

Mr. ELLIS having left the Chair, it was taken by the newly elected President, Dr. MARCET, who thanked the Fellows for the honour they had done him in electing him to that office.

FEBRUARY 15TH, 1888.

Ordinary Meeting.

WILLIAM MARCET, M.D., F.R.S., President, in the Chair.

THOMAS STYLES AINGE, Municipal Buildings, Liverpool;
JOHN CHARLES BELL, F.R.G.S., Langburgh Hall, Great Ayton;
CHRISTOPHER ALEXANDER MARKHAM, Sedgebrook, Northampton;
SURGEON-MAJOR SAMUEL SMITH, F.A.S., Kingsdown Parade, Bristol;
JOHN THOMAS TIBBLES, High Street, Melton Mowbray; and
JOHN WALTHER, M.D., West House, Eastbourne,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"ELECTRICAL AND METEOROLOGICAL OBSERVATIONS ON THE PEAK OF TENERIFFE." By the HON. RALPH ABERCROMBY, F.R.Met.Soc. (p. 101.)

"RAINFALL OF SOUTH AFRICA, 1842-1886." By W. B. TRIPP, M.Inst.C.E., F.R.Met.Soc. (p. 108.)

"SOME METHODS OF CLOUD MEASUREMENTS." By NILS EKHOLM. (p. 124)

CORRESPONDENCE AND NOTES.

THE RAINFALL OF INDIA. By H. F. BLANFORD, F.R.S., F.R.Met.Soc.

MR. BLANFORD, in his paper on "The Rainfall of India," gives the following interesting account of the rainfall distribution of India:[1]—

At the opening of the calendar year, the rainfall is in a transitional phase, and, in the Indian area, almost suspended. In the extreme south of the Peninsula, the weather is clearing after the final showers of the autumnal rains of the Carnatic; the barometric depression, towards which blows the north-east monsoon of the Bay, having retreated southwards, till it lies south of Ceylon; and the vapour brought down by the latter is discharged as rain in the coasts of Ceylon and in more southerly latitudes. On the other hand, in the extreme north-west, in the Punjab and on the mountains around, after two or three months of bright clear skies and a falling temperature, a cloud canopy is gathering overhead; light, but damp and somewhat oppressive southerly winds are setting in over Northern and Central India; the barometer falls steadily; and after some days' incubation, a barometric depression appears or is rapidly formed in some part of North-western India, or the more elevated country to the west of the Indus; and for two or three days snow falls more or less copiously on the hills and rain on the Punjab Plains. In some cases, this depression moves eastward towards the North-west Provinces and Bengal, carrying the rain with it, which, however, becomes lighter as it extends to the south-east. At other times, the depression seems to be almost stationary, and after a few days becomes obliterated at or near the place of its origin. As an almost invariable rule, each spell of rainy and snowy weather is followed by a wave of high barometric pres-

[1] *Indian Meteorological Memoirs*, Vol. III. Part II. p. 117.

sure, sweeping forward from the Indus Valley and bringing cool dry north-west winds.

In most seasons, these spells of rain occur several times in succession during the cold season, beginning usually about Christmas and becoming more frequent as the new year advances, up to March or the beginning of April. These are the cold weather rains of Upper India. It can scarcely be said that, as yet, their rationale is quite satisfactorily explained; chiefly as regards the incipient cause of the barometric fall which ushers them in. I have given in the text what appears to be at least a partial explanation; but there occur at all times of the year oscillations of atmospheric pressure, the primary seat of which appears to be the higher strata of the atmosphere, and the cause and nature of which are at present very obscure. These doubtless play a part in the production of the barometric depressions. The subsequent stages of the disturbance are more easily traceable. The rain is generally restricted to the east and the north of the depression; and the vapour which feeds it is brought up by the southerly winds which, on such occasions, prevail in Northern and Central India; sometimes also in the North of the Bay and of the Arabian Sea. Much of this vapour is doubtless furnished by evaporation from the warmer land surface of the Peninsula, as well as from the sea surface; but the winds which collect it are not improbably, in their origin, the return current of the anti-monsoon, which has descended within the tropical zone, when the northern limit of that monsoon has retreated to the south of the Bay. On this point, however, I cannot speak with confidence.

The winter rainfall is restricted to Northern India. It is heaviest and most regular in the Northern Punjab, is less so on the Gangetic Plain, Eastern Rajputana, and Central India, where, indeed, it sometimes fails almost completely; and is least frequent in Bengal, where December is the most rainless month in the year. It reaches its maximum in March or April in the extreme north; in February and March between the parallels of 28° and 32° North latitude, in the Southern and Eastern Punjab and the adjacent districts of the North-west Provinces; and in the latter part of January in Oudh, the eastern half of the Gangetic Plain and Central India.

Meanwhile the temperature of the Indian Peninsula is rapidly rising under the increasing heat of the re-ascending sun. On the coast line, diurnal sea-winds begin to set in as early as January; and by the month of March, a barometric minimum is established in the interior of the Peninsula, extending up through Chutia Nagpur to the Lower Gangetic Plain (where, indeed, at all times of the year, the pressure is slightly lower than in Central India). By this time, a general indraught of air, most active in the day time, has been set up around the coasts, the directions varying in accordance with the cyclonic law; and thus, west winds prevail on the coast of Malabar, south-east to south winds on that of the Carnatic, and south winds on that of the Northern Circars, Orissa, and Bengal. The vapour brought by these sea-winds is condensed chiefly in local diurnal storms over the south and east of the Peninsula and in Bengal; more abundantly on and around hills, which assist in promoting a convective ascent of the air, than on the plains; and most copiously of all in the permanently damp province of Assam and Cachar. This rainfall increases steadily during April and May, with the increasing heat of the land area and the fall of atmospheric pressure; which fall is greater in Northern than in Southern India.

But the Bombay Presidency, north of Dharwar, and indeed Western India generally, south of the Punjab, is rainless, or nearly so. The prevailing winds of this region (still in accordance with the cyclonic law) are chiefly north-west; coming from the arid Mekran Coast, or descending from the plateau of Beluchistan and the higher western mountains, and then sweeping the equally waterless and partly desert plains of Sind, Western Rajputana, and Cutch, they become highly heated in their course, and, as hot winds, prevail in Western and far into Central India. In March and April too, they frequently blow, chiefly as day winds, right across Northern India to Bengal; but are rarely felt in the Gangetic delta itself, since they pursue their eastward course at the higher level attained on the Chutia Nagpur plateau, while the sea-winds from the coast creep in beneath, and, eddying with the westerly winds, give rise to the local storms termed Nor'westers, which are so characteristic of the spring months in Lower Bengal. As the season advances, easterly winds from the sea make their way further inland, up to the Gangetic plain, and especially along the foot of the Himalaya, giving rise

to the frequent thunderstorms of the mountain zone and the dust storms of the plains.

Thus the storm rainfall of the spring months, and especially of May, is heaviest and most frequent in Eastern Bengal and Assam, on the coasts of the Burmese peninsula, and on the Ghâts of Travancore. But it amounts to upwards of 5 ins. on an average over all the hilly and elevated portion of Southern India, on the Eastern Ghâts (Jeypore, &c.) in the north-east of the Peninsula, in Chutia Nagpur, and in a narrow zone along the southern face of the Himalaya. The rainfall of these months is higher in the Punjab Himalaya than in Kumaon and Nepal; but this is due to the frequent rain of March and April, which, as above explained, is similar in character to the winter rain.

During these spring months, on the Bay of Bengal and the Arabian Sea, the winds are light, frequently alternating with calms, and somewhat variable; though chiefly from south-west on the former, and northerly and in May westerly on the latter sea. The change which ensues at the end of May or in June, when the surrounding seas are swept by a strong monsoon current, and heavy and continued rain sets in on the coasts of India, is very marked, and has long been recognised in popular language as 'the Burst of the Monsoon.' The essential cause of the change appears to be that, during the spring months, the sea-winds which feed the storms of that season are the relatively damp, but by no means saturated, air of the surrounding seas; or if saturated, at least not so to any considerable vertical height above the sea surface. But in more southerly latitudes, in the neighbourhood of the Equator, is a belt of the atmosphere corresponding to the doldrums of the Atlantic, into which the south-east Trades of the South Indian Ocean pour a steady supply of almost saturated air. At all times of the year, more or less convection goes on in this belt, as is proved by its raininess at all seasons; and consequently it affords a great reservoir of air, which, up to an indefinite height above the sea surface, borders at all times on a state of saturation. Now it appears to be the eventual rush of this air towards the region of low pressure, developed over India gradually during the spring months, that constitutes the burst of the monsoon. Once started, the energy of its movement is sustained by the condensation of its own copious vapour; by the latent heat so set free. The energy of convection, furnished by the heated atmosphere of the plains, is competent only to keep up the feebler indraught that obtains during the spring months; and indeed, even this indraught is maintained partly by the moderate condensation of cumulus and local thunderstorms, fed by the vapour it brings. The solar heat, directly absorbed by the dry land atmosphere or taken up from the heated ground, bears much the same relation to the general air movement as the pull of the trigger does to the propulsion of the rifle ball. It determines the disturbance of atmospheric equilibrium, but it does not furnish the energy of the resulting air-stream. That energy is supplied in the latent heat of the indrawn vapour. So long as this supply is small, and limited to the shallow stratum of air immediately fed by the evaporating surface beneath it, so long is the air movement feeble and interrupted. And it is only when the barometric gradient from south to north has become sufficiently great to tap the great reservoir of latent energy, supplied by the evaporation of the south-east Trade zone, that the air current becomes strong and sustained, constituting the summer monsoon; sustained, too, long after the heated land surface has been in a great measure quenched and cooled by the rainfall.

Even before the monsoon has set in on the coasts of India, it sometimes happens that a rush of saturated air from this persistent vapour reservoir is temporarily directed into the bosom of the Bay, or more rarely of the Arabian Sea. Such, as Mr. Eliot has shown, is the condition that determines the formation of those severe cyclones that characterise the spring months, and more especially May in certain years. In all their essential features, except their greater violence and the intensity of their barometric depression, they are identical with the cyclonic storms, generated, from time to time, over Bengal or on its coasts, during the height of the summer monsoon; and indeed, in most years, the first burst of the rains on the coast itself is accompanied with such a storm. But whether, as Mr. Eliot has endeavoured to demonstrate, and, as seems probable, owing to the inferior depth of the saturated air current that feeds them, or to other causes yet to be ascertained, these severe cyclones of the spring months are less durable than the milder storms of the rainy season, and are speedily diverted or broken up as soon as they are intercepted by even a low hill range.

The rain-bearing monsoon is first felt on the west coast of Ceylon about the middle of May, and shortly afterwards on that of Travancore, and in most years reaches Bombay about a fortnight later. This branch blows on the west coast of India from directions between west and south-west. Being directed against a coast, parallel to which, at an average distance of 50 or 60 miles, runs the steep escarpment of the Western Ghâts, from 2,000 to 7,000 feet in height, and being forced to surmount this range to reach the region of lower pressure in the interior, in consequence of expansion and dynamic cooling suffered in the ascent, it precipitates on the face of the Ghâts and the undulating or hilly country at their foot a rainfall which varies, according to locality, from 100 to over 250 inches in the five months of its prevalence. On the lee side of the range, the rainfall rapidly decreases; falling in the course of about 50 miles to 30 inches, and in some places to less than 20 inches. But the plateau of the Deccan and Mysore is swept, throughout the season, by a strong westerly wind, the average movement of which, as registered by anemometers at no great elevation from the ground surface, varies from 150 to 350 miles a day. The plains of the Carnatic, being under the lee of the highlands of the interior, receive but little rain during the height of the monsoon; and indeed, in the southern half of this province, the average rainfall of both June and July is less than that of May. The hilly country to the north of the Godavery delta, as well as the narrow coast plain of the Northern Circars, has a higher rainfall; but this is in some measure received from the Bay of Bengal.

On the west coast, the rainfall reaches its maximum at Honawar in latitude 14° 30′ N, a little north of the common boundary of the Madras and Bombay Presidencies. At this place it exceeds 130 inches during the five months of the monsoon. It declines northward, falling to 72 inches at Bombay and to 41 at Surat. Still further north, on the coasts of Kathiawar, Cutch, and Sind, although the monsoon blows with unabated strength, having an average diurnal movement of more than 400 miles at Kurrachee, it has no longer the same rain-bearing capacity; and the form and physical circumstances of the land surface are no longer so favourable to precipitation. As on the Deccan plateau, so in Lower Sind and Cutch, the land surface is swept by a strong wind, night and day; but rain rarely falls; and at Bhuj, in Cutch, the average precipitation of the five months is barely more than 14 inches. At Kurrachee it is only 6 inches.

Another great branch of the monsoon sweeps up the Bay of Bengal as a south-west wind. This is directed, with but little obliquity, on the coasts of Tenasserim, Pegu, and Arakan, the first and last of which, like the west coast of India, are the sea-board of narrow strips of low land, fringing parallel ranges of hills. On these coasts, accordingly, the rainfall is as heavy as on that of Malabar, indeed heavier, since, at Sandoway, it is but little short of 200 inches, and at Akyab and Tavoy over 170 inches. On the coast of Pegu, however, on the margin of the Irrawadi delta, it amounts to less than 100 inches, and decreases rapidly inland, till, at the head of the delta, it has fallen to less than half that amount. At the head of the Bay, the lower stratum of the current becomes more southerly, and as it sweeps the Gangetic delta, it bends round westward and blows up the Gangetic Plain and along the southern face of the Himalaya as an easterly wind. A portion of the higher stratum, however, is not so diverted, but preserves a south-west course over the hills of Tipperah, and the Khasi, Jyntia, and Naga Hills towards Upper Assam, carrying to that province and Cachar a rainfall which varies from 40 to upwards of 100 inches. On the plains and in the valley, it amounts as a rule to between 50 and 60 inches only, but on the face of the Khasi Hills, which present a steep scarp running athwart the course of the current, the forced ascent of the air produces that enormous precipitation which has made Cherra Punji famous. According to our present registers, this is not much less than 400 inches in the five monsoon months.

The two branches of the monsoon—the one a westerly wind sweeping across the whole Peninsula, the other an easterly wind occupying the fringing plain of the Himalaya—accordingly meet in Northern India. Between them lies the debateable ground of Chutia Nagpur, South Behar, and a part of the Central Indian plateau. This is the seat of a barometric trough, a region of relatively low pressure, which is more or less persistent throughout the monsoon. Within this tract, the easterly and westerly winds alternately hold sway; the former predominating to the north of the Ganges and Jumna, the latter on the higher land

to the south. The cyclonic storms already mentioned, which, in some seasons, are successively formed in Bengal or on its coasts, usually travel westwards along this trough or follow a track somewhere between the Satpuras on the south and the northern margin of the Gangetic Plain. As may be seen by comparing the rainfall chart, Plate VII., with the isobaric charts of the monsoon months on Plate V., the axis of the trough of low pressure is also one of minimum rainfall; but to the south of it, a band of relatively high rainfall runs across the head of the peninsula including Chutia Nagpur, the Central Provinces, Rewah, Bhopal, and Malwa; and to the north, another band of high rainfall skirts the Himalaya range. The former of these, the southern rainfall band, marks the zone in which the convective ascent of the western branch of the monsoon is, on the whole, most active; and it will be seen in the second part of this Memoir, that the Provinces that lie within it, and more especially the Central Provinces and Chutia Nagpur, have a more regular rainfall, one subject to smaller vicissitudes, than most other provinces of India; than any, indeed, excepting Bengal and Assam, which lie in the eastern prolongation of its axis.

As above remarked, the axis of the barometric trough is also one of minimum rainfall. To the north-west both the barometric depression and the zone of low rainfall open out and widen; both elements, moreover, declining in that direction, until the seat of the absolute minimum, both of pressure and rainfall, is reached in Upper Sind, the Lower Punjab and the adjacent States of Bahawalpore, Khyrpore, and a portion of Western Rajputana. Here the average rainfall of the summer monsoon barely exceeds 3 inches, and in some years fails completely. It is almost needless to remark that this also is the seat of the highest temperature throughout the rainy season. This, then, is the focus of the area in Northern India, towards which the Indian branches of the monsoon are directed. It is the seat of persistent minimum pressure, but not that of maximum air convection, as is sufficiently indicated by the absence of rain. The heat of this tract by rarifying the atmosphere and keeping the barometer low, determines it as the goal towards which the two branches of the monsoon flow; but the heat does not furnish the energy of the monsoon's movement, for this is supplied by the latent heat set free in the condensation of its vapour.

Beyond and to the west of the Indus, in Beluchistan, the summer season is practically rainless. At Quetta, the prevailing wind is from north-west, changing occasionally to north, west, and, chiefly in July, to south-west, but in all months north-west is the dominant quarter. It is this persistence of land winds that explains the aridity of the Indus valley; for the south-west direction, that prevails in the valley itself, is merely that which is given to the current by the trend of the hills that bound it.

Thus then, from three sides, we have air poured in towards the seat of barometric depression in India. On the fourth, the north side, the Himalaya bars access to any air current in at least the lower half of the atmosphere. Of this indraught, the monsoon from the sea is the strongest and steadiest current, and predominates to such an extent, that hitherto its existence alone has been recognised. And this pre-eminence it enjoys, in virtue of its being that which carries within it, in a superlative degree, the source and fount of energy in a latent form, viz., the latent heat of its abundant vapour. But the north-west and west winds of the western frontier, if subordinate, are far from playing an unimportant part in the meteorology of the summer season. It is to them that is due the normal rainlessness of the Indus valley and the western desert; during breaks in the rains and in such seasons as 1877, they frequently prevail far down the Gangetic Plain and over Eastern Rajputana and Central India; and it is apparently to their partially supplanting or perhaps mingling with, and diluting, the sea-wind that blows on the Concan and in the Deccan, that is due the drought that, in certain seasons, prevails in Western India.

Usually, in September, the monsoon from the sea ceases to penetrate to North-western India; but it continues a full month longer in Bengal; its goal, in the latter half of September and the beginning of October, being the outstanding barometric depression in Chutia Nagpur. Gradually, with the greater rise of pressure in Northern India, this depression is transferred southwards, or to south-east, over the Bay. North-east winds set in on the Orissa coast, and a good deal of rain falls in the eastern coast of the Peninsula, and sometimes penetrates far into the interior. About the middle of October, it has reached the latitude of Madras,

where, up to this time, the rainfall has been but scanty. Heavy and continued rain, now, for the first time, falls in the Carnatic; and this is essentially the rainy season of all the south-eastern portion of the Peninsula. It lasts through November and well into December; but, by Christmas, the chief seat of barometric depression has been transferred to the equatorial sea, and the north-east wind (the winter monsoon), which continues to blow on the Madras coast, carries its vapour unprecipitated to lower latitudes; the condition with which we started at the outset of this Summary.

RECENT PUBLICATIONS.

AMERICAN METEOROLOGICAL JOURNAL. Vol. IV. Nos. 9-11. January-March 1888. 8vo.

The principal articles are:—Instruments for measuring Atmospheric Pressure, by F. Waldo (17 pp.). This is an abstract of lectures given to the officers of the Signal Service School of Instruction at Fort Myer in 1884.—A new Thermometer Exposure, by H. A. Hazen (5 pp.).—A thirty-day period of Thunderstorms, the Moon, and the Weather, by H. H. Clayton (3 pp.).—Meteorological Observations during the Solar Eclipse of August 19th, 1887, made at Chlamostino, Russia, by Winslow Upton and A. L. Rotch (10 pp.). The results of these observations may be summarised as follows:—The temperature and humidity fluctuated, as is usual in eclipses, the former showing a fall, and the minimum occurring a few minutes after the total phase, and the latter showing a rise, which in this eclipse was to the saturation point. The minimum temperatures recorded by a thermometer in the shade, and by black or white bulbs *in vacuo* freely exposed, differed but a few tenths of a degree from each other, and were also a few tenths lower than the air temperature at 4.13 a.m., 23 minutes before sunrise. Minute fluctuations of barometric pressure and of the wind's direction and velocity were observed, which cannot with certainty be attributed to the eclipse, but which in the case of the wind can be so ascribed with some probability. The cloud tints show the appearance of clouds, some of which were within and others without the region of the eclipse. The most marked features observed were the long-continued deposit of dew and the great brightness of the landscape during the total phase.—The Climate of Southern Russia and Iowa compared, by Dr. G. Hinrichs (19 pp.).—The Organisation of the Meteorological Service in some of the Principal Countries of Europe, by A. L. Rotch (15 pp.). In 1885 and 1887 the author visited the headquarters of the various meteorological services in Europe, and now proposes to give an account of each. In the present paper he deals with the organisations in Germany.—A Classification of the Winds, by W. M. Davis (8 pp.).—Pressure and Temperature in Low and High Areas, by H. A. Hazen (3 pp.).

ANNALES DU BUREAU CENTRAL MÉTÉOROLOGIQUE DE FRANCE, publiées par E. MASCART, Directeur, Année 1885. 4to. 1887.

Part I. (318 pp. and 32 plates) is devoted to thunderstorms and various memoirs. The chief papers are:—Resumé des orages en France et de l'état de l'atmosphère pendant l'année 1884, par E. Fron.—Sur la propagation des orages, par M. Plumandon.—Etudes sur le climat de Fécamp, par A. Angot.—Etudes sur le climat de Paris. Deuxième partie. La pluie depuis 1688, par E Renou.

Part IV. (112 pp. and 14 plates) is devoted to general meteorology, and in addition to the observations made at the French Consulates abroad during 1885, contains the following papers:—Etude sur le climat de la Guadeloupe, par M. Boname.—Note sur l'importance des hautes pressions de l'Asie, par L. Teisserenc de Bort.—Etude sur la circulation générale de l'atmosphère, par L. Teisserenc de Bort.

ANNUAIRE DE LA SOCIÉTÉ MÉTÉOROLOGIQUE DE FRANCE. September 1887-January 1888. 4to.

The principal articles are:—Sur les causes d'une classe de bourrasques, par M. Hauvel (7 pp.).—Projet de prévision automatique du mistral à l'aide d'un appareil

électrique, par M. Arabeyré (2 pp.).—Etude sur les dépressions secondaires du golfe de Gênes et observations relatives à leur prévision, par G. Guilbert (8 pp.). —Remarques théoretiques sur les mouvements gyratoires de l'atmosphère, par H. Lasne (12 pp.).

CIEL ET TERRE. Revue populaire d'Astronomie, de Météorologie, et de Physique du Globe. March 1st-April 16th, 1888. 8vo.

The principal meteorological articles are:—Le climat de l'Europe ancienne, par J. C. Houzeau (7 pp.).—L'eau tombée et l'évaporation à la surface de la terre (2 pp.).—Pluie ou neige par ciel serein (3 pp.).—La densité de la neige, par A. Lancaster (9 pp.).—Distribution de la température à la surface du globe (5 pp.).—Les "rouleaux" de neige (3 pp.).

DIE REGEN-VERHÄLTNISSE DES RUSSISCHEN REICHES. Von H. WILD. V. Supplement-band zum Repertorium für Meteorologie. Mit einem Atlas. 4to. 1887. 95 + cclxxxvi. pp.

This is an account of the rainfall of the whole Russian Empire, a subject already treated of by Wesselowskij in his work on the Climate of Russia. This latter paper dealt with 62 stations, and closed with the year 1852. Prof. Wild's inquiry, carried out by Wahlén, deals with 450 stations, and closes with the year 1882. It treats not only of the amount, but also of the frequency, the variability, the maximum fall in 24 hours, and the geographical distribution of the fall. It is illustrated with large maps on the same scale as Prof. Wild's temperature maps.

ERGEBNISSE DER METEOROLOGISCHEN BEOBACHTUNGEN IM JAHRE 1886. Herausgegeben von dem Königlich Preussischen Meteorologischen Institut durch WILHELM VON BEZOLD, Director. 4to. 1888. lvi. + 223 pp. and map.

This contains the daily observations at 12 stations and the monthly results at 176 stations in connection with the Prussian Meteorological Institute for the year 1886. There is also a report on the thunderstorm observations for 1886; an account of the hurricane which passed over the Krossen district, on the Oder, on May 14th, 1886; and a note on the snowfall from December 19th to 22nd, 1886, in Central Europe.

JOURNAL OF THE ASIATIC SOCIETY OF BENGAL. Vol. LVI. Part II. No. 1. 1887. 8vo.

Contains a paper by Mr. H. F. Blanford, F.R.S., on the influence of Indian Forests on the rainfall (15 pp.). The general conclusion to be drawn from the facts set forth in this paper is that, while no one of the instances cited fulfils the requirements of scientific proof, the tendency of the evidence they afford is uniformly favourable to the idea that the presence of forest increases the rainfall.

METEOROLOGISCHE ZEITSCHRIFT. Herausgegeben von der oesterreichischen Gesellschaft für Meteorologie und der deutschen meteorologischen Gesellschaft. Redigirt von Dr. J. HANN und Dr. W. KÖPPEN. February-April 1888. 4to.

The principal articles are:—Die Regenverhältnisse des Russischen Reiches, von H. Wild (10 pp.). This is a review by Dr. Hann of the work noticed above.—Zur Ableitung einer periodischen Function aus einer Reihe nach gleichen Zeit-intervallen beobachteter Grössen, von N. Ekholm (11 pp.). This is a development of a paper by the author in Vol. XX. of the *Zeitschrift der oest met. Gesellschaft* (1885).—Beiträge zur Gewitterkunde, von Dr. C. Ferrari (20 pp.). This is an investigation of the thunderstorm phenomena at different levels in Italy, for which the stations in the Po area, which are at very various levels, afford valuable material. Among the most important conclusions are the following:—The violence of electric action increases with rapidity of advance of the storm, and at all levels the relation of the thunderstorm to the course of the isobars and isotherms remains unchanged. Before the storm pressure and relative humidity fall and temperature rises so that each reach their extreme at the moment of the storm breaking out, then each reverse their course and often reach their extremes in the opposite direction at the end of the storm. The wind velocity increases during the storm; it is calm just before and dies away just after the

storm. The usual shape of the thunderstorm depression is an ellipse with the major axis perpendicular to the line of advance. The temperature depression which follows is also an ellipse with its major axis perpendicular to the storm axis. The strongest wind is in the direction of the advance of the storm, the larger the storm the stronger the wind. Hail falls in belts parallel to the advance. —Beiträge zur Kenntniss der Gewitterperioden, von Dr. H. Meyer (6 pp.).—Ueber die leuchtenden (silbernen) Wolken, von O. Jesse (4 pp.). This is an attempt to explain the phenomenon of luminous clouds by the ejection of gases from Krakatoa, which rose to such a level that they were condensed and crystallised, the small crystals reflecting the sunlight.—Ueber eine Methode die elektrische Natur der atmosphärischen Niederschläge zu bestimmen, von J. Elster und H. Geitel (5 pp.).—Ueber einige Methoden für Wolkenmessungen, von N. Ekholm (7 pp.).—Ueber die Häufigkeit beobachteter Luft-Temperaturen in ihrer Beziehung zum Mittelwerthe derselben, von Dr. A. Sprung (5 pp.).

PROCEEDINGS OF THE ROYAL IRISH ACADEMY. Science. Series II. Vol. IV. No. 6. January 1888. 8vo.

Contains:—On the Distribution of Temperature over Great Britain and Ireland, by H. Hennessy, F.R.S. (11 pp. and map). The author shows that, in islands surrounded by waters whose temperature is in excess of that of the air, the distribution of temperature must be represented by isothermal lines similar in outline to the coast of the islands, and with the centres of the isothermals transported in the direction of the nearest pole of the earth. Mr. Hennessy maintains that the variation of temperature with height is far from being correctly represented by those who assume, for every part of the surface of islands and continents, a decrease of 1° Fahr. for every 300 feet of altitude. So-called corrections of temperature made on this assumption might be more truly called systematic interpolations of errors.

REPORT OF THE FIFTY-SEVENTH MEETING OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, held at Manchester in August and September 1887. 8vo. 1888. c. + 971 pp.

The principal meteorological paper and reports read at the Meeting and printed in this volume are:—Observations of Atmospheric Electricity, by Prof. L. Weber.—The General Bibliography of Meteorology and Terrestrial Magnetism, compiled by the Signal Office at Washington, by C. Abbe.—On the Hygrometry of Ben Nevis, by H. N. Dickson.—On the Thermal Windrose at the Ben Nevis Observatory, by A. Rankin. The observations discussed were for the three years ending May 1887. The winds, arranged in their order of highest yearly mean temperature, with their respective temperatures, are:—

S.	SW.	W.	NW.	SE.	E.	N.	NE.
32°·6	32°·5	31°·4	30°·2	30°·2	27°·8	27°·6	26°·5

—On the different kinds of Thunderstorms, and on a scheme for their Systematic Observation, by the Hon. R. Abercromby.—Contributions to Marine Meteorology from the Scottish Marine Station, by Dr. H. R. Mill.—The direction of the upper currents over the Equator in connection with the Krakatoa Smoke-stream, by E. D. Archibald.—Report of the Committee appointed for the purpose of investigating the circulation of underground waters in the permeable formations of England and Wales, and the quantity and character of the water supplied to various towns and districts from these formations. To this report is appended a chronological list of works referring to underground water from 1659 to 1887.

REPORT ON THE METEOROLOGY OF INDIA in 1885. By HENRY F. BLANFORD, F.R.S., Meteorological Reporter to the Government of India. 4to. 1887. 517 pp.

As this begins a second decade of the annual volumes, Mr. Blanford refers to the progress that has been achieved during the past ten years. He says:—"More important, however, than the mere accumulation of meteorological statistics and their reduction to average values, has been the advance made in the knowledge of the meteorological processes which regulate the climatic conditions of India. The varying characteristics of the monsoons, the conditions of cyclone formation in the Bay of Bengal, and the courses which storms follow

at different seasons, the distribution of the rainfall and the vicissitudes to which it is subject, have all engaged the special attention of the officers of the department, and with results which have greatly enhanced the economic utility of the current registration of weather phenomena. They have led to a great extension of the system of flood warnings to the coasts of the Bay, to the establishment of a system of flood warnings for the alluvial tracts of the Western Presidency, and to the issue of forecasts of the character of the monsoon rains, based on the meteorological features of the earlier months of the year. The year 1885 has furnished a very striking instance in confirmation of the hypothesis on which these latter forecasts have been principally based, viz. that the persistence of dry North-westerly winds in Western India and Westerly winds in Northern India, is greatly influenced by the depth and extent of the snow accumulation on the North-West Himalaya. It has also furnished an equally striking instance of the tracking of a storm, day by day, in its progress up the Bay of Bengal on a very unusual course, solely by means of the changes of the winds and the barometer readings at stations around the coast. But the year also afforded a reminder of the inadequacy of the storm-warning system, as originally established, to fully utilise the information yielded by the reports; and the disaster which attended the onset of a storm-wave on the coast of Orissa has been the immediate occasion of extending the system of warnings to all the principal ports of the Bay."

RESULTS OF METEOROLOGICAL OBSERVATIONS MADE IN NEW SOUTH WALES DURING 1885, UNDER THE DIRECTION OF H. C. RUSSELL, B.A., F.R.S., Government Astronomer. 8vo. 1887. 167 pp. and 8 plates.

The year 1885 was a year of serious drought, although the total rainfall for the year was only 10 per cent. below the average; but this was owing to the very heavy rainstorm which came into the Colony on the north-west, and travelled right across to the sea, in many places depositing 10 or 11 inches in two days. This was at the end of January, and produced a fine crop of grass that in a great measure warded off the serious consequences of the drought which followed during the greater part of the year. Taking the mean temperature for the whole Colony for fifteen years, we find it is 61°·3, and the mean for 1885 is 63°·0, or 1°·7 in excess of the mean. Even at Sydney, where the heat is tempered by the sea-breeze, the temperature this year is 63°·9, or 1°·3 above the mean temperature. The absence of cloud, therefore, and drought has had a decided effect upon the temperature of the whole Colony. Hence it would seem that rainfall and temperature have a direct relation, which is another link in the connection between our seasons and the Trade Winds; for when these winds are unusually far south, there is more heat and less rain. If we could obtain similar data for all parts of the world, it would probably appear that the temperature of the tropics generally was above the average during 1885, and the extra energy thence derived would lead the Trade Winds to more energetic southerly motion towards us. If this series be a true statement of fact, then we must look for something outside our earth as the source of this influence on the light and heat derived from the sun; but what it is that does this no one is yet prepared to say.

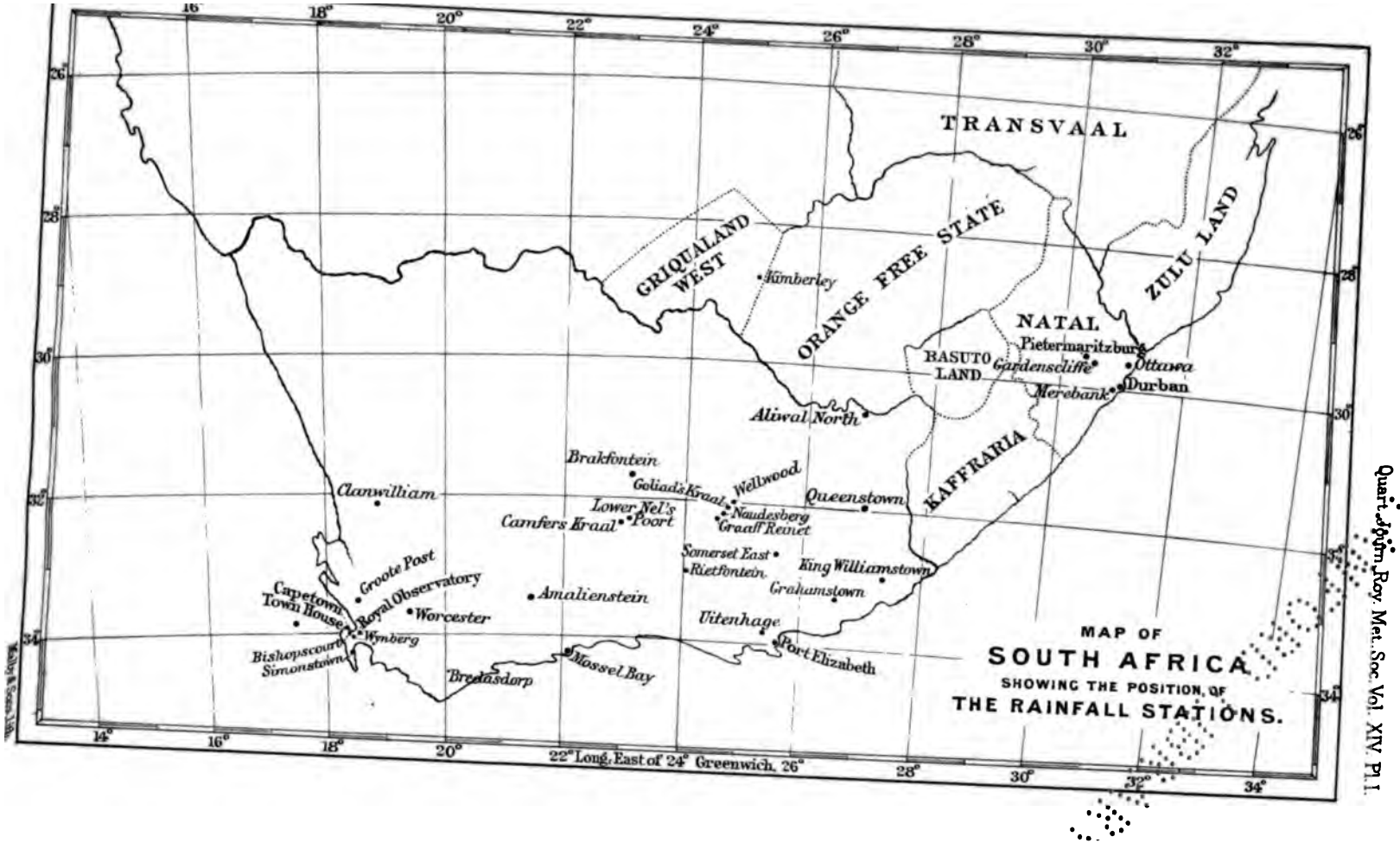
SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. Vol. XXIII. Nos. 265-267. February-April 1888. 8vo.

The principal articles are:—English Thunderstorms (2 pp.).—The January Blizzard (1 p.).—Isonephs. Maps of Cloud-prevalence over the Globe (4 pp.).—The Bolide of November 20th, 1887, by H. G. Fordham (3 pp.).—The Snowstorms over North-east England and East Scotland, March 11th to 16th, 1888 (5 pp.).—The Effect of Snow on the Springs, by Dr. G. Burder (2 pp.).

THE SCOTTISH GEOGRAPHICAL MAGAZINE. Vol. IV. No. 2. February 1888. 8vo.

Contains a paper on Burma, by Sir C. Bernard (17 pp.). The author states that the rainfall varies widely in different parts of Burma. Along the coast at Akyab, Kyoukphyoo, Sandoway, Moulmein, Tavoy, Mergui, the average rainfall, as registered for many years back, exceeds 200 ins. a year. At Bassein, Rangoon, and Pegu, a little way inland, it averages 100 ins. Up the broad

rawaddy Valley the rainfall decreases rapidly, till at Prome it is 42 ins. and Thayetmyo it is only 37 ins. Information regarding the rainfall in Upper Burma is meagre. But there is evidently a dry belt, with only 30 ins. or under of rain a year, from Thayetmyo to Myingyan. Then as the hills get nearer the river the rainfall increases to about 45 ins. at Mandalay; to about 60 ins. at Katha; and perhaps to 80 ins. at Bhamo. On the Upper Chindwin, at the Ruby Mines, along the base of the Shan Hills and in the narrow valleys of the Salween and Sittang, the rainfall is heavy. These great variations of rainfall cause corresponding differences in the agriculture and the ways of the people. For instance, about Myingyan, Pagán, and the dry belt, rice fields of the Lower Burma give place to fields of cotton, millet and pulse, such as are seen in the drier parts of peninsular India. Near and above Mandalay rice again appears as the staple product. Owing to the heavy rainfall in the delta and on the mountains, the Irrawaddy and all the rivers of Burma are subject to great floods in the rainy season. At Prome, nearly 200 miles from the sea, and about 100 miles beyond tidal influence, the height of the River Irrawaddy has been observed day by day for twenty-five years, and the difference between the lowest dry season level and the highest rainy season level is 44 feet. In ordinary years the rise is probably about 35 or 36 feet. At the point where these observations are taken the river is about 1 mile broad. When these heavy floods come down the rivers rise high above their banks and spread themselves over the country. Sometimes the water of the Irrawaddy spreads over a breadth of 20 to 25 miles of delta country. Even at Mandalay, 500 miles from the sea, the river covers a breadth of 5 miles during the rainy season.



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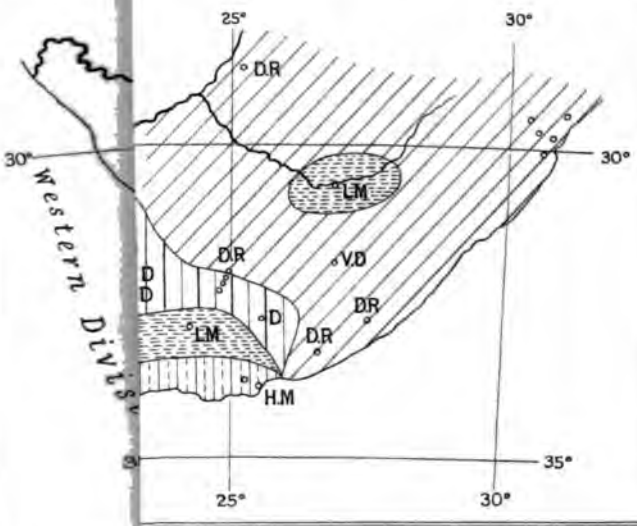

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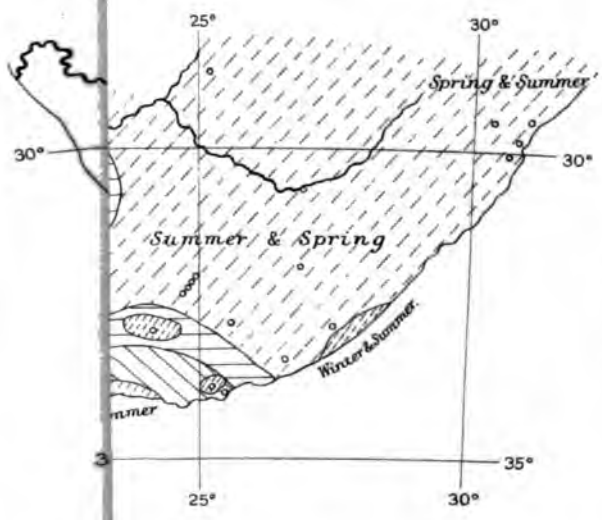

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W. = V ept. = Winter.
H.M. = H ec. = Spring.

QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY.

VOL. XIV. JULY 1888. No. 67.

ADDRESS

DELIVERED AT THE

Annual General Meeting of the Royal Meteorological Society,

ON JANUARY 18TH, 1888.

Including a Discussion of the Greenwich Observations of Cloud during the Seventy Years ending 1887.

BY WILLIAM ELLIS, F.R.A.S., of the Royal Observatory, Greenwich,

PRESIDENT.

THE time has now arrived when it becomes my privilege to address you for the second and last time from this chair. On the occasion of my first address you were kind enough to listen to a statement of my general views and thoughts on matters meteorological. In the year since elapsed, a very short time in the history of science, such views do not in general become much modified, so that having delivered myself on that occasion, I feel that in the same direction I can now add with advantage little to what I may previously have said. I had at one time thoughts of trying to give on the present occasion some review of meteorological work during my period of

office, but eventually this appeared to me to be too large a subject for the compass of an address, besides which I have had no sufficient leisure to prepare such review, in the complete and systematic manner in which it should be done. Finally it occurred to me that, as contrasting with my previous address, I might this evening ask your attention to some results of observation, to which, however, I will not further allude until I have spoken of some other matters on which I wish to say a few words.

Firstly, I would desire to congratulate the Society, as I think I may, on the satisfactory position in which, as a scientific Society, it now stands, and on its apparently increasing usefulness. The ordinary work of the Society is well known. It has a system of observing stations at which meteorological observations are made on a definite plan, with instruments properly tested in the first instance, and afterwards periodically examined as necessary. The observations made with these instruments are regularly checked in the office of the Society, and the results printed and communicated to the Fellows in the *Meteorological Record*, in addition to the publication in the *Quarterly Journal* of many excellent papers read at the ordinary meetings of the Society. It is, of course, difficult for us, with the limited means at our command, to carry out any expensive original or experimental work. But we can act with advantage in other ways. The Society may largely influence volunteer workers throughout the country, incite them to united action for any particular object or special line of inquiry, and so enable much to be usefully accomplished which might not otherwise become so readily done. The late action of the Society in directing attention to the desirability of taking photographs of lightning affords one illustration of this, a large number of photographs having in a very short space of time been most kindly and freely communicated to the Society in response to our request, which photographs we hope before long to exhibit to the Fellows of the Society. In the same connection we trust now, in addition, to organise a body of workers for the regular and systematic observation of the phenomena of thunderstorms, and so accumulate a large amount of valuable information thereon.

I have alluded to our *Quarterly Journal*. In regard to it, I think the Society may be well satisfied with the varied as well as interesting character of the communications which during late years we have received, and from foreign as well as from home contributors. It is also a matter of congratulation that we have amongst us and about us those who, alike able and willing, are ever ready to undertake, in addition indeed to ordinary duties sufficiently onerous, the preparation of papers on those accidental and occasional phenomena, such as great storms or floods, which are not only most effectively treated when taken in hand at once, but the material for the satisfactory study of which can also be so much more readily obtained immediately after the occurrence of the particular phenomena than at any future time.

Whilst speaking of the Society and before passing to other subjects, I should like to ask the attention of the Fellows to one other matter. Our Officers and Council are at present elected at the Annual General Meeting of the Society by the Fellows then assembled. This plan confines the election

to a small section of our Fellows, and, remarking the practice in this respect of various other scientific Societies, I was induced to suggest to the Council that we should, like them, adopt some scheme by which Fellows residing at a distance from London might participate in the election, without the necessity of attending the Annual Meeting. It appeared to me that any change which tended to bring our provincial Fellows into closer relation with the Society, and especially one giving to them a voice in the election of our Officers and Council, could not but be beneficial. But grave doubt was expressed as to whether our Charter and By-laws would permit such change to be made. Still I am bold enough to say, I trust with no presumption, that I see nothing myself in the Charter to prevent what I have mentioned being done, and By-laws can be amended or altered. Our existing system is founded on others arranged in times when postal facilities were very different to what they are at the present time, and I think that it is now only proper that our provincial Fellows should enjoy the privilege of voting, whether they may choose to exercise it or not, instead of necessarily confining the election to the comparatively small number of Fellows who are able to attend the Annual Meeting. Having thus stated my own view, I shall now leave the question in the hands of the Fellows for future consideration, should it be thought to be one deserving attention.

In my previous address I alluded to the endeavours which have from time to time been made to discover a sympathetic connection between the varying aspect of the sun, as indicated by the solar spots, and the meteorological condition of the earth; so far a somewhat disappointing branch of inquiry. I then pointed out the different relation in which, in this respect, magnetism practically stands, inasmuch as a broad relation between solar spots and magnetism has undoubtedly been established, a position of the question which has not yet been reached on the meteorological side. True, the further advance in magnetism is less rapid, one question that now confronts the inquirer in that direction being the nature of the relation which may subsist between special solar outbreaks and magnetic storms, and the cause of the smaller irregular magnetic fluctuations. As regards the broad effect, having a period of eleven years or thereabouts, discussion of the observations made at a single station is sufficient to establish the fact of sympathetic connection between solar and magnetic change, from the circumstance that increase and decrease in the number and magnitude of sun spots is accompanied by increase and decrease of the diurnal magnetic variation. But a similar treatment of atmospheric phenomena, or of the changes of any meteorological element, fails to give similar conclusive results, and on the whole it seems doubtful whether any relation with the assigned physical cause has yet been satisfactorily made out. The successful treatment of the problem seems now to require that it should be dealt with in some far more comprehensive manner than has hitherto attained, preparatory to which it may be necessary that atmospheric phenomena generally throughout the globe, and not simply what occurs at certain stations, should be studied for a long period and on a wider scale than has yet been the case. This would hand over the settlement of the question to

a future generation. For at present our meteorological stations are distributed over the earth in such isolated clusters that any complete discussion, not only of this but also of other meteorological problems, seems impracticable, until we are able to correct the great inequalities that in this respect exist. An inspection of the map prepared by Mr. Scott and contained in Volume XI. of the *Quarterly Journal*, will show what vast regions of the earth are at present totally unrepresented, presenting thus a striking contrast to the multitudes of stations to be found in the more thickly populated centres. We speak of the difficulty of dealing with ocean meteorology and with the meteorology of the upper atmosphere, but we have not yet covered the land. Apart from the consideration of varying solar influence, which, though interesting, may be of secondary importance, we are not yet, in spite of our millions upon millions of observations, in a position to indicate with precision either the general meteorological conditions of our globe at any epoch, or the changes which occur from year to year over such portions of its surface as we might command. Only probably by international effort and unity of action could such things be done.

But such questions may probably not have much interest for some of my hearers, who may be inclined to say that what meteorology requires is something more practical, more weather telegrams and better synoptic charts. But this is perhaps only to state much the same thing in another way. All tends to the same end. I, at any rate, have nothing to say against synoptic charts, indeed, in my previous address, I think I spoke of their value in no uncertain way. The impulse which they have given to the study of atmospheric changes as a whole, as compared with the previous necessarily more partial treatment, has in some aspects revolutionised meteorology, only unfortunately they are at present confined to isolated areas of the world. In this connection the thoughts of some of our Fellows will no doubt turn to the work[1] recently published by one whom we are happy to reckon as belonging to, and working also for, our own Society, the exposition of weather science contained in which, whilst highly interesting to meteorologists, has also, I believe, attracted the attention of other readers. No doubt the newer meteorology, the study of the changes occurring from day to day, is a noble one, but other matters do also require attention. There are things that are highly interesting for their own sake, independently of the question of practical benefit, and we must sometimes come from the general to the particular. For instance, some amongst us find delight in taking monthly means of meteorological elements, probably for their place of residence, and comparing them with previous monthly means, or in similar work of a quiet kind, and if others who conceive that they have higher and loftier views think that these move in but a narrow circle, their work has still its own value. The meteorological characteristics of a place must have intense interest for the inhabitants of that place for many reasons, whatever may be going on, say, in the North

[1] *Weather, a Popular Exposition of the Nature of Weather Changes from Day to Day* By the Hon. Ralph Abercromby.

Atlantic. And if in getting out his means such a man should drop in a decimal more than is absolutely necessary, it takes no appreciable time to get that other decimal, so that it need not so frequently vex those who may have no affection for similar pleasures. If it be allowable to speak in scriptural phrase, we might say, "Let every man be fully persuaded in his own mind." We must take a many sided view of our science, for it would evidently be a misfortune if we all wished to do the same thing. Rather is it matter for congratulation that we do so differ in our inclinations. Besides, the jewel is sometimes found in a very unexpected quarter. So then let each one work in the way that seems best to him. If the meteorological pendulum does sometimes swing too far in one direction, there is no fear but that it will return, nay probably become drawn too far in an opposite direction. But remembering how frequently, by a simultaneous movement in the minds of men, perhaps of different countries, important discoveries in science have been made, sometimes in part by one and in part by another, at other times independently by several nearly at the same time, we need scarcely fear that any really important branch of inquiry will ever long remain neglected.

I should like now to say a few words upon another question, in its relation to meteorological observations and work, with a view to the introduction of a more uniform system of exhibiting meteorological results. I refer to the manner of counting time. The practice of astronomers is to commence the day at mean noon, counting the hours on to 24, whilst in civil affairs the custom is to commence with mean midnight, and divide the day of 24 hours into two periods of 12 hours each, a custom necessarily much employed in scientific work other than astronomical. But in the closer relations between the workers in different branches of physical science which the progress of inquiry has brought about, the existence of two systems of counting time becomes an inconvenience. Besides there is the further, if perhaps less pressing question, of different countries counting from different meridians, rendering desirable also the adoption of some system of universal time for use in the record of such independent physical phenomena as become observed over a large extent of the earth's surface, as, for instance, earthquake shocks, or a Krakatoa explosion. These questions became indeed discussed at two successive International Conferences, held in the years 1883 and 1884 respectively, and, with a view to united action, certain recommendations were made, but with small practical effect. The Americans had indeed solved the universal time question in a practical way before the meeting of the first of the conferences mentioned. With the astronomical aspect of the time question, about which there are undoubted difficulties, we have here no direct concern. But because of these difficulties there is no reason why reform should not be made in other directions. When meteorological work has been undertaken by an observer of astronomical habits or conjointly with astronomical work in one and the same observatory, it has happened that, astronomical time being employed for the record of meteorological phenomena, the observations or results have been grouped according to the astronomical day. This seems to me unfortunate. For since the sun is the ruling agent in all meteorological

phenomena, the day from noon to noon does not appear to be the natural meteorological day, but that from midnight to midnight, as reckoned indeed by meteorologists generally. At Greenwich, however, in spite of the astronomical character of its observatory, meteorological results have always been grouped according to the civil day, the hours since 1885 having been further counted from 0h. (midnight) continuously to 24h. And I would recommend all meteorological observers without exception, including those who take only one or two observations daily, to adopt the same system of counting the hours continuously from midnight to the midnight following, and abandon altogether the "a.m." and "p.m." reckoning. Those who give hourly values of meteorological elements might for a time insert "midnight" for 0h. or 24h., and "noon" in place of 12h., to obviate possibility of mistake. And I would argue for something further. The sun being as before mentioned the ruling meteorological agent, the time employed for meteorological observations and records[1] should not, I conceive, be mean solar time but true solar time, that is, sun-dial time, or what sailors call apparent time. The substitution of mean solar time for sun-dial time was not, meteorologically speaking, an advance. For any comparison of the relation between the daily march of an element, such as temperature, in the two months of February and November, is vitiated by the circumstance that in the former case mean solar time is in advance of true solar time, and in the latter case in retard, the extreme difference between the middle of February and the beginning of November being as much as 30 minutes of time. If the inequality in the solar motion were greater than it is, the difference would have to be dealt with, but in the actual case it becomes neglected. Should, however, for any meteorological element for the record of which mean solar time has been employed, the harmonic constants have been calculated, the daily march of the element as referred to true solar time can be obtained therefrom, but it is not always desired to employ the harmonic method. The question of the use of true solar time for meteorological work is one to which I think attention may well be drawn as deserving some consideration. At present, however, mean solar time is in universal use.

In such reference to hours of the day as I may have to make in what will here follow, I propose to employ the method above recommended of reckoning from 0h. mean midnight, and counting the hours on to 24h., the following midnight, and shall designate time so reckoned Greenwich civil time.

There is another matter to which I desire also to make some reference, that of the formation of daily means from hourly values of any meteorological element. You are aware that the daily mean in some cases given is that of the twenty-four hourly values, beginning with midnight and ending with 23h., and in other cases that of the twenty-four values beginning with 1h. and ending with the following midnight. If the values of the meteorological element for 0h. and 24h. be similar, either method would give the same daily

[1] And not only for meteorological observations, but also for any physical or natural phenomena having relation with the solar diurnal period.

mean, but since this rarely occurs, that is since the element is not strictly periodic, a small error is in either case committed. In the former case instead of representing the actual day from midnight to midnight, it represents one beginning half-an-hour before midnight and terminating half-an-hour before the following midnight, and in the latter case one beginning half-an-hour after midnight and terminating half-an-hour after the following midnight. A more correct daily mean, and one which applies to the day from midnight to midnight, is found, as General Strachey points out,[1] by adding together the hourly values of the element from 1h. to 23h., half the value for 0h., and half the value for 24h., and dividing the sum by 24. My object in referring to the matter here is simply to show that in general no very alarming error is committed whichever of the two slightly erroneous methods of taking the mean may be employed. Consider a practical case. Suppose, for instance, that on any given day the mean of the twenty-four hourly values of barometer reading from 0h. to 23h. is taken to form the daily mean. And assume that the value for 24h. exceeds that at 0h. by 0·240in. Then the mean obtained by substituting the 24h. value for the 0h. value, that is the mean of the twenty-four values from 1h. to 24h., will be greater than the former mean by 0·010in. The more correct mean, taken as before mentioned, will be found to be 0·005in. greater than that first found, and 0·005in. less than that last found. Or the error made in either case is the $\frac{1}{48}$th part of the difference between the values for 0h. and 24h. That is to say, the difference between the readings at these hours must amount to 0·480in. in order to affect the daily mean in either case by 0·010in. Correspondingly in mean daily temperature it would require that the values for 0h. and 24h. should differ by 4°·8 to affect the daily mean by 0°·1. Thus although, as General Strachey very truly says, it is to be regretted that meteorologists have not yet adopted any uniform system in this respect, it is satisfactory to know that in all ordinary cases the error committed is small, so that the results of past work may on the whole be accepted as comparative with means properly taken; indeed, if thought necessary, special correction could be applied for such few cases as may seem to require it. But in future it might be well that such daily means should be taken in the more correct way. So much for daily values. As regards monthly means, when formed from twenty-four mean hourly values, the error made in taking the mean in either of the two slightly erroneous ways is altogether insignificant.

Speaking of monthly means brings to mind another meteorological difficulty, the difference in the length of the different months, and especially the shortness of February. But even if the months of February and March be equalised, there remains the fact that the first six months of the year contain only 181 days, and in leap year 182, whilst in the remaining six months there are 184 days. To give the months in leap year alternately 30 and 31 days, and drop

[1] In a paper "On the Computation of the Harmonic Components of a Series representing a Phenomenon recurring in Daily and Yearly Periods." *Proceedings of the Royal Society*, Vol. 42.

one day in some month in common years would to some extent better equalise the months and seasons, but even if some such system could be adopted there would be a break of continuity in the comparison with old results. It may be mentioned that in the *American Journal of Science and Arts* for the year 1866, methods are given for correcting monthly means for the error caused by the unequal length of the calendar months. The more general adoption of the system of five day means would be one way of arriving at greater equality in the formation of normal values of meteorological elements.

Another question arising out of what we have just been considering, and one on which my own opinion has been more than once asked, is, having a series of mean hourly values of some meteorological element, say through a month, how to deal with the non-periodic part of the diurnal variation. Only in exceptional cases will the variation be truly periodic: usually there is break of continuity. Whether we wish to exhibit our results graphically in curves, or whether we desire to apply the harmonic method, this circumstance requires to be dealt with, especially in elements in which the magnitude of the non-periodic portion of the variation is relatively large. Assuming the non-periodic change to have been uniform, it may be taken practically into account in the following way. Suppose the particular case to be that of the diurnal barometric inequality. The excess of the value for 24h. above that for 0h. should be applied proportionately to the several hourly values in such way that the commencing values are increased and the terminating values diminished, leaving the mean value unaltered. Considering the curve which the values would form, the process is equivalent to, in a manner, twisting it about on its middle point until the values for 0h. and 24h. agree. Or more accurately the ordinates on one side of the middle point are increased in proportion to their distance from that point, and correspondingly diminished on the other side, until those for 0h. and 24h. have the same value. Similarly for annual or other periods. The treatment is indeed equivalent to that described by General Strachey in the paper to which reference has been already made.

I now at last come to my promised results of observation. On different occasions during my two years' term of office the subject of clouds has been brought before the Society by papers and discussions in various ways. It thus appeared to me that I might fitly close my tenure of office by endeavouring to put before the Society something in regard to another aspect of the cloud question; the numerical variation of its amount in different years, in different months of the year, and at different hours of the day, as determined from all the observations that have been made at Greenwich. This was the more readily done because I had some time since put together some portions of the material now employed. It may not be exactly modern meteorology, perhaps only a backward swing of the meteorological pendulum, but we may yet with advantage study the meteorological characteristics of given localities which, as affecting vegetation and crops, must still remain matter of prime interest to the localities concerned, besides which the characteristics of one place may be an index to those of a

considerable surrounding district. In any case it is well to discuss observations, made frequently with great labour, and see what results they will yield.

The materials at command for the present purpose are the following:—

I. A series of observations made at the Royal Observatory, Greenwich, extending from the year 1818 to the year 1840, and including always two observations, and in a few years three observations daily.

II. Another Royal Observatory series, extending from the year 1841 to the year 1847, during which period twelve observations were made daily at the even hours of Göttingen time, excepting on Sunday and a few other days, when a less number of observations were made.

III. A third Royal Observatory series, commencing with the year 1848 and still continued, including here the results to the year 1887. The observations in 1848 were made six times daily, at 6h., 9h., 12h., 15h., 18h., and 24h. of Greenwich civil time, and in the remaining years four times daily, at 9h., 12h., 15h., and 21h., of Greenwich civil time, the observations on Sunday being in both cases made at slightly different hours. [The year 1848 is here included, because, as will be seen further on, although the hours of observation in that year were different to those of following years, no practical difference in the monthly values is thereby produced.]

IV. A series of observations extending from the year 1818 to the year 1855, made by Mr. J. H. Belville, Astronomical Assistant, until October 1822, at the Royal Observatory, and afterwards at his private residence in different parts of the town of Greenwich, two observations being taken daily, and three during very many years.

The observations in Series I. were made by the Astronomical Assistants of the Observatory. These were discontinued on the establishment of the Magnetical and Meteorological Department of the Observatory, the observations commencing Series II. being made by a new set of observers under the direction of one of the Astronomical Assistants (Mr. Glaisher), to whom the direction of the new department was given, and whose successors in unbroken line have continued to make the observations of Series II. and III. to the present day.

In order to make Series I. and IV. comparative throughout as regards monthly means, only two observations daily were included in forming them. The two observations employed are described in both series (when mentioned at all, which is only occasionally, this not having been the age of printed forms), sometimes as "morning" and "afternoon" observations, and sometimes as "a.m." and "p.m." observations. Whether particular hours are to be understood, or the period generally, seems uncertain. The third observation in Series IV. is styled a "night" observation, it was probably a late evening one; the third Observatory observation when taken was probably also a late evening one. On some days on which observations were deficient in one series the observations of the other series were taken to complete the daily values before taking monthly means. And occasionally when observations were wanting in both series, daily values were assumed

from a consideration of the weather notes. There were other small difficulties in a few months of Series IV., into the particulars of which it is scarcely necessary to enter. The results of Series I. and IV., though thus comparative as regards hours of observation, are not similarly comparative with the results of Series II. and III.

The series all include results for Sunday, excepting Series II.; for since the results in this series depend on observations made every two hours, the few Sunday observations that were taken could not properly be employed. Except in a few extreme cases the omission of Sunday results will affect in comparatively only a slight degree the separate monthly means, but in no case can such omission practically influence general means.

The results of the four series of observations follow herewith. Throughout the series 0 represents a clear sky and 10 one that is overcast. In Series I. and IV. no monthly means whatever had been taken; these had all to be formed specially for this work. The results given in Series II. and III. are either taken directly from the several volumes of Greenwich Observations, or deduced from the values given therein, excepting for some of the early years of Series III., for which abstracts of the original observations had to be prepared, and monthly means formed. In a few cases small errors found to exist in the values as printed have been corrected.

SERIES I.—ROYAL OBSERVATORY, 1818 to 1840. MEAN MONTHLY AMOUNT OF CLOUD AS DEDUCED FROM TWO OBSERVATIONS ON EACH DAY.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly Mean.
1818	7·1	6·4	6·7	6·5	5·4	4·3	5·5	5·7	6·0	5·7	6·8	7·0	6·09
1819	6·0	6·8	7·9	5·1	6·2	6·5	6·2	5·9	6·1	6·5	7·4	6·6	6·43
1820	7·2	7·1	5·9	5·1	5·7	6·6	7·0	5·4	5·3	6·0	7·6	8·8	6·48
1821	8·5	5·6	6·5	5·7	6·4	6·3	6·5	5·5	6·8	5·4	6·6	6·2	6·33
1822	7·1	4·7	5·4	6·0	4·2	4·0	6·3	5·4	5·2	6·3	5·3	5·5	5·45
1823	8·3	7·2	7·3	6·0	4·6	5·8	7·2	6·6	4·0	5·7	7·5	5·8	6·33
1824	6·6	7·0	7·4	5·7	6·9	6·5	6·0	6·5	5·5	6·5	6·6	6·0	6·43
1825	7·2	7·4	5·8	4·7	5·7	4·5	3·6	5·9	5·0	6·5	6·1	6·9	5·77
1826	6·0	6·2	5·7	5·9	5·7	3·5	5·1	4·3	5·3	5·8	6·0	7·3	5·57
1827	6·9	5·7	5·9	5·6	6·0	5·8	4·3	6·4	6·9	6·0	6·6	6·7	6·07
1828	7·3	6·7	5·9	6·8	5·5	5·2	6·9	5·9	4·7	4·9	6·0	6·9	6·06
1829	7·3	7·8	6·2	6·9	4·1	5·2	6·4	6·8	5·3	6·1	7·0	8·6	6·48
1830	8·5	7·1	4·3	5·5	5·9	7·0	6·3	5·6	5·8	5·3	4·7	7·0	6·08
1831	7·3	5·8	6·7	7·0	5·4	5·6	5·5	6·1	6·6	6·6	7·0	6·1	6·31
1832	7·0	6·4	6·5	5·4	6·6	7·1	6·1	6·6	4·6	6·4	6·6	6·8	6·34
1833	6·7	7·6	7·4	6·5	3·4	5·5	6·5	6·4	5·5	6·0	6·8	7·0	6·27
1834	7·0	6·3	6·2	5·6	4·1	5·4	6·5	6·0	5·6	4·7	7·5	6·5	5·95
1835	7·2	6·2	7·0	5·7	6·7	5·6	3·3	4·7	6·4	6·6	7·0	7·1	6·12
1836	7·0	6·8	6·6	7·5	3·7	6·8	5·3	5·9	7·5	6·7	6·8	7·7	6·53
1837	8·6	6·6	6·9	7·4	6·7	4·3	5·6	5·7	5·7	6·0	5·7	7·2	6·37
1838	7·5	6·9	5·9	6·9	5·7	6·9	6·9	6·4	6·2	6·8	7·2	7·2	6·71
1839	6·6	6·9	7·5	6·9	5·1	6·3	7·0	6·6	6·5	6·4	8·2	7·4	6·78
1840	6·4	7·4	6·0	3·7	6·4	6·1	7·6	5·3	5·8	5·5	5·5	6·8	6·04
Means	7·19	6·63	6·42	6·00	5·48	5·69	5·98	5·90	5·75	6·02	6·63	6·92	6·22

SERIES II.--ROYAL OBSERVATORY, 1841 to 1847. MEAN MONTHLY AMOUNT OF CLOUD AS DEDUCED FROM TWELVE OBSERVATIONS ON EACH DAY, EXCEPTING SUNDAY, MADE AT THE HOURS OF GÖTTINGEN TIME.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly Mean.
1841	6·88	8·74	4·89	6·62	5·46	6·40	7·28	6·48	5·71	7·03	7·19	6·69	6·61
1842	7·82	7·33	7·27	4·42	5·78	4·49	5·79	4·85	6·50	6·17	7·53	7·13	6·26
1843	7·32	7·95	6·23	6·40	7·27	7·19	7·48	5·98	4·58	6·38	7·12	8·54	6·87
1844	7·53	6·71	7·03	3·94	6·34	5·87	6·93	6·18	5·88	6·57	8·34	8·55	6·66
1845	8·60	6·64	6·57	5·67	7·93	5·64	7·32	6·53	6·39	6·26	6·54	6·28	6·70
1846	7·81	7·74	6·81	7·62	6·53	4·68	6·65	7·57	5·87	7·88	7·44	6·76	6·95
1847	7·08	7·33	5·83	6·76	6·03	6·76	5·64	7·07	6·61	7·60	6·86	7·93	6·79
Means	7·58	7·49	6·37	5·92	6·48	5·86	6·73	6·38	5·93	6·84	7·29	7·41	6·69

It appeared to me that, having done this much, it would be an interesting thing to endeavour to connect together these four series of results and incorporate them into one general table. In proceeding to do this it may be first noticed that the monthly means of Series II., 1841 to 1847, and those of the first year of Series III., the year 1848, are not strictly comparable with those of the remaining years of Series III., 1849 to 1887, because of the observations having been made at different hours. But remarking the length of the latter group, it was considered better to reduce the 1841-1848 observations to that standard, which has been done by aid of the two-hourly values for each month found from the series of observations 1841-1847, and given in Table III. Comparing in each month the mean of the values for 9h., 12h., 15h., and 21h., interpolated from those contained in this table, with the mean of the twelve two-hourly values, it was found that to make the monthly values of the 1841-1847 group comparative with those of the 1849-1887 group, the former values in March and April should be increased by 0·15, and in May, June, July, August, September and October by 0·20, no alteration being necessary in January, February, November and December. The 1848 values depending on observations at 6h., 9h., 12h., 15h., 18h., and 24h. required no change. Thus we obtain values from 1841 to 1887, referred to the mean of four observations at 9h., 12h., 15h., and 21h., daily, as given in Table I.

We have thus one Royal Observatory Series, 1818-1840, Series A; another Royal Observatory Series, 1841-1887, Series B; and a Belville Series, 1818-1855. Remarking that the Belville Series extends over portions of both the Royal Observatory Series, it becomes interesting to use the Belville Series to connect together the Observatory Series A and B, since the Belville Series and the Observatory Series A are presumably deduced from observations taken at similar hours, whilst the results in the Observatory Series B depend on observations taken at different hours. Such plan of proceeding seemed better than applying to the Observatory Series A through so many years corrections deduced simply from the values given in Table III., because it would tend also to eliminate anything like personal difference between observers.

SERIES III.—Royal Observatory, 1848 to 1887. Mean Monthly Amount of Cloud as deduced from Four Observations on each Day, made usually at 9h., 12h., 15h., and 21h. (excepting in the Year 1848, as already mentioned.)

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly Mean.
1848	8·1	7·7	7·9	7·4	3·0	7·4	6·6	7·6	5·6	7·3	6·7	6·7	6·83
1849	7·9	6·7	8·0	7·8	7·7	6·5	5·9	7·1	7·0	6·9	6·9	7·1	7·13
1850	8·4	7·3	6·8	8·2	7·4	4·7	7·9	7·4	7·4	7·2	7·1	8·2	7·33
1851	6·9	7·2	8·0	8·3	7·1	6·5	8·0	7·0	6·3	8·0	6·4	8·6	7·36
1852	6·2	6·8	6·3	5·0	8·0	8·6	4·8	6·8	6·9	7·0	8·4	7·9	6·89
1853	7·4	8·2	7·2	8·7	6·1	7·7	8·3	7·7	6·7	7·8	7·5	7·9	7·60
1854	8·0	6·4	6·1	4·7	6·9	8·2	7·3	6·8	4·2	6·4	7·3	5·9	6·52
1855	8·7	8·0	7·8	5·8	7·7	6·9	7·0	5·9	5·4	7·4	8·1	7·0	7·14
1856	7·6	8·4	8·0	6·8	8·1	6·9	7·1	6·2	6·7	7·3	7·4	7·4	7·32
1857	7·5	6·8	7·8	7·8	6·1	4·8	6·4	5·7	5·8	6·6	8·2	7·2	6·73
1858	5·6	5·1	5·4	6·2	7·0	5·2	6·9	5·2	7·1	6·6	7·0	7·7	6·25
1859	7·5	6·3	7·2	6·9	6·1	7·4	5·1	6·5	6·9	7·2	5·9	7·2	6·68
1860	6·9	6·5	7·5	7·0	6·5	7·9	8·3	8·3	7·4	6·8	7·9	7·9	7·41
1861	7·0	7·4	6·5	7·1	7·6	7·4	7·4	5·9	6·3	6·5	6·9	6·5	6·87
1862	7·8	8·5	8·9	7·3	8·3	7·8	7·2	6·9	7·7	7·1	7·3	7·5	7·69
1863	7·3	6·5	6·4	6·6	6·3	7·2	5·0	7·0	6·9	7·2	7·0	6·8	6·68
1864	6·8	7·8	6·9	5·6	6·3	7·0	6·4	5·3	6·2	6·8	6·5	7·9	6·63
1865	7·2	7·8	7·7	4·2	6·4	5·9	6·5	7·0	3·2	6·2	6·2	8·3	6·38
1866	7·5	7·2	8·1	6·3	6·1	6·9	7·0	7·7	7·8	7·3	6·1	7·4	7·12
1867	7·3	7·7	7·9	7·4	6·6	6·1	7·0	6·2	6·3	6·5	6·9	7·9	6·98
1868	8·4	6·3	6·4	6·9	4·9	4·4	4·9	6·5	5·2	5·8	7·8	7·4	6·24
1869	7·2	7·2	7·7	6·1	7·4	6·3	5·7	5·9	6·6	5·5	6·4	6·5	6·54
1870	6·5	7·4	7·5	4·0	5·6	6·4	6·6	6·2	4·3	6·2	6·1	8·1	6·24
1871	8·0	7·8	5·7	7·1	5·6	8·0	6·8	3·9	6·8	5·9	5·9	6·8	6·52
1872	6·9	7·2	6·5	5·6	6·9	6·5	6·1	6·2	6·4	6·8	7·1	7·1	6·61
1873	6·9	9·2	6·5	6·5	7·0	7·2	6·0	6·3	5·6	6·9	7·4	7·2	6·89
1874	6·7	7·1	6·5	5·8	6·8	6·4	5·7	6·8	6·8	7·2	6·6	7·2	6·63
1875	7·4	7·8	7·8	5·7	6·0	6·5	7·5	6·9	5·7	7·8	8·1	7·9	7·09
1876	7·6	7·5	6·5	6·2	5·2	6·5	5·5	5·1	6·6	7·5	7·0	8·1	6·61
1877	6·8	7·4	7·2	8·4	7·1	5·0	7·0	7·0	6·5	6·3	6·1	7·1	6·83
1878	7·8	8·4	7·7	6·4	7·1	6·5	6·9	7·3	6·2	6·6	7·9	7·6	7·20
1879	7·8	8·8	6·8	7·9	7·0	7·7	8·5	7·2	6·7	7·1	6·9	7·6	7·50
1880	6·3	6·9	6·1	7·4	6·4	7·8	7·2	7·3	6·1	7·1	6·2	7·6	6·87
1881	6·8	8·5	5·9	6·7	5·4	6·6	6·1	7·4	7·1	6·1	7·4	7·1	6·76
1882	8·2	8·0	5·6	6·4	5·5	8·1	6·5	7·0	6·9	7·6	6·5	8·2	7·04
1883	7·2	6·7	5·6	6·4	6·3	6·7	7·5	6·3	6·1	7·2	5·9	8·0	6·66
1884	8·0	7·0	6·8	7·5	5·5	6·7	7·1	4·6	5·9	6·7	6·7	8·2	6·72
1885	7·9	7·3	6·3	5·9	6·8	5·5	5·4	6·9	6·8	7·7	7·7	7·0	6·77
1886	7·2	7·8	7·5	6·9	6·8	6·5	6·5	6·0	6·1	7·4	7·0	6·0	6·81
1887	7·6	6·2	6·8	5·8	7·8	5·0	4·6	5·7	7·7	6·7	7·1	7·0	6·50
Means	7·37	7·37	7·00	6·62	6·56	6·68	6·60	6·52	6·35	6·90	6·99	7·42	6·86

On comparing the Observatory Series A with the Belville Series, it appeared that these series from their commencement until the year 1880, with the exception of occasional discordance in the last two or three years, were practically identical, being made as it would seem almost entirely by Mr. Belville. But beginning with the year 1881, the numerical values in the two series

SERIES IV.—BELVILLE, 1818 TO 1855. MEAN MONTHLY AMOUNT OF CLOUD AS DEDUCED FROM TWO OBSERVATIONS ON EACH DAY, MADE UNTIL 1822 OCTOBER, AT THE ROYAL OBSERVATORY, AND AFTERWARDS IN DIFFERENT PARTS OF THE TOWN OF GREENWICH.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly Mean.
1818	7·1	6·4	6·7	6·5	5·4	4·3	5·5	5·7	6·0	5·7	6·8	7·0	6·09
1819	6·0	6·8	8·0	5·1	6·2	6·5	6·2	5·9	6·1	6·5	7·4	6·6	6·44
1820	7·2	7·1	5·9	5·1	5·7	6·6	7·0	5·4	5·3	6·0	7·6	8·8	6·48
1821	8·5	5·6	6·5	5·7	6·4	6·3	6·5	5·5	6·8	5·4	6·6	6·1	6·32
1822	7·1	4·7	5·4	6·0	4·2	4·0	6·4	5·4	5·3	6·3	5·3	5·5	5·47
1823	8·3	7·2	7·3	6·0	4·6	5·8	7·2	6·5	4·0	5·7	7·5	5·8	6·32
1824	6·3	7·0	7·4	5·6	6·9	6·5	6·0	6·5	5·4	6·5	6·6	6·0	6·39
1825	7·2	7·4	5·8	4·7	5·6	4·5	3·6	5·9	5·0	6·5	6·1	6·9	5·77
1826	6·0	6·2	5·7	5·9	5·7	3·5	5·1	4·3	5·3	5·8	6·0	7·5	5·58
1827	7·0	5·6	6·1	5·6	6·0	5·8	4·3	6·4	7·0	6·1	6·7	6·6	6·10
1828	7·6	6·8	6·0	7·1	5·5	5·1	6·7	6·1	4·7	4·9	6·0	7·0	6·13
1829	7·0	7·7	6·2	7·0	4·3	5·4	6·3	6·5	5·6	6·3	7·1	8·5	6·49
1830	8·6	6·8	4·6	5·5	5·5	7·1	6·0	5·8	5·9	5·7	4·8	6·7	6·08
1831	7·4	5·7	6·5	6·7	4·5	5·5	4·9	5·7	6·3	5·7	6·5	5·9	5·94
1832	6·9	6·7	6·4	4·5	5·5	6·3	5·6	5·6	4·0	6·3	6·7	6·5	5·92
1833	7·5	7·2	6·8	6·2	3·1	5·1	5·8	5·5	5·1	5·0	6·7	7·1	5·92
1834	6·6	5·7	5·4	5·2	3·4	3·9	5·8	5·4	5·0	4·2	7·1	6·1	5·32
1835	6·5	5·5	5·9	5·1	5·7	5·1	2·6	4·2	4·9	6·7	6·9	6·8	5·49
1836	6·8	6·0	6·7	7·1	3·3	6·6	5·4	6·0	6·7	6·7	6·9	7·8	6·33
1837	8·5	6·6	6·6	6·6	5·8	4·5	5·7	5·8	5·4	6·3	5·9	7·5	6·27
1838	7·5	7·3	5·8	6·6	5·1	6·9	6·4	6·4	6·1	7·0	7·3	7·4	6·65
1839	6·8	6·7	7·4	6·3	4·5	6·1	6·6	6·2	6·4	6·3	7·9	7·5	6·56
1840	5·9	6·8	5·8	3·1	6·0	6·3	7·2	4·9	6·1	5·3	5·5	6·6	5·79
1841	6·9	8·2	5·1	6·4	5·8	6·3	7·5	6·4	5·5	7·3	7·3	7·1	6·65
1842	8·0	7·2	7·1	4·8	5·6	4·1	6·0	5·0	6·8	6·3	7·5	7·0	6·28
1843	7·3	7·9	5·8	6·3	7·1	6·8	6·7	5·5	4·2	5·9	6·6	8·1	6·52
1844	6·6	6·3	6·3	4·0	5·8	5·6	6·5	6·0	5·9	6·8	8·3	8·8	6·41
1845	7·8	6·2	6·2	5·4	7·5	6·2	7·0	7·1	6·7	6·4	6·2	6·7	6·62
1846	8·0	7·5	6·6	7·3	5·5	3·5	5·8	7·6	5·7	8·1	7·0	6·7	6·61
1847	7·5	7·2	5·8	5·8	5·5	6·2	5·7	6·5	5·3	7·4	7·0	7·8	6·48
1848	7·7	7·0	7·5	6·8	3·0	6·9	6·2	7·6	5·7	7·5	6·4	6·6	6·57
1849	7·5	6·4	6·6	6·7	6·8	5·4	4·8	6·3	6·4	6·4	6·7	6·8	6·40
1850	8·2	7·0	6·0	7·0	6·9	4·1	7·1	6·5	6·4	6·5	6·2	7·1	6·58
1851	6·2	6·0	7·6	7·5	6·7	5·4	6·9	5·8	5·4	7·1	5·9	8·3	6·57
1852	5·8	6·0	5·4	4·2	7·0	7·2	4·1	6·4	6·7	6·9	8·2	7·1	6·25
1853	7·0	7·5	6·3	7·8	5·3	7·7	7·6	6·9	6·6	7·4	6·8	7·5	7·03
1854	7·7	5·6	5·7	4·0	6·6	7·4	6·1	6·3	3·7	6·0	7·7	6·3	6·09
1855	8·6	7·6	7·4	5·2	7·2	6·4	6·5	6·3	5·8	7·4	7·7	6·3	6·87
Means	7·24	6·66	6·32	5·85	5·56	5·71	5·98	5·99	5·66	6·32	6·77	7·01	6·26

sensibly differ, and the various handwriting which from this time appears in the Observatory books seems to show that the observations are those of several observers, although the hours of observation in both series were probably similar or nearly similar throughout. This difference is more or less maintained until the end of the Observatory Series A in the year 1840, the values in the Observatory Series for the years 1831-1840 being the

greater on the average in January by 0·1, February and March 0·3, April 0·5, May 0·7, June 0·3, July, August and September 0·4, October 0·2, and in November and December 0·1, indicating apparently a difference of method in estimating cloud.

Comparing together the monthly values of the Observatory Series B from 1841 to 1855 with the corresponding Belville values, it was similarly found that the Observatory values were the greater in January by 0·3, February 0·5, March, April and May 0·6, June and July 0·7, August and September 0·4, October and November 0·3, and in December 0·2. In this case the differences include that due to different hours of observation as well as any difference in the method of estimating cloud.

Briefly, then, the values in the Observatory Series A and the Belville Series practically agree up to the year 1830, whilst the remaining values of the Observatory Series A, 1831 to 1840, are greater than those of Belville, although as regards hours of observation, all are so far as is known comparative. The values in the Observatory Series B, 1841 to 1855, are also greater than the corresponding Belville values in much the same way. The values in the Observatory Series A to 1830 being essentially the Belville values, no further consideration is here given to them.

Thus, to form a general table, we have Belville values 1818 to 1855, and Observatory values 1831 to 1887. The values for the period 1841-1887 are already settled as they appear in Table I. As regards the previous years, 1818 to 1840, the differences found by comparing the Belville values 1841-1855 with the corresponding values of Observatory Series B were applied to the Belville values 1818 to 1840, and the resulting values for the years 1818 to 1830 are those to be found in Table I. But for the years 1831 to 1840 these reduced Belville values were combined with the corresponding values of Observatory Series A, the means of the values of the two series being those given in Table I. For considering that the values in these years in Observatory Series A exceed the Belville values by amounts on the whole not very different from those by which the values 1841-1855 of the Observatory Series B exceed the corresponding Belville values, the Observatory values 1831 to 1840 (neglecting the small difference due to difference of hours of observation, since these cannot exactly be known) may be taken as fairly comparative with those of the Observatory Series B commencing 1841. That is to say, we get for the years 1831 to 1840 two independent sets of values, one the reduced Belville values, the other the values from Observatory Series A, which during these years are independent of Belville, the means of the two sets of values being taken, as already mentioned, to form those given in Table I. Thus we obtain for the years 1818 to 1887 a general table in which the monthly values of cloud are referred to the mean of four observations taken at 9h., 12h., 15h., and 21h., daily. For the years from 1848 to 1887 the numbers are simply a repetition of those of Series III.

As well as giving mean monthly values for the whole period, means are given also for the seven ten-yearly periods which the table contains. In

TABLE I.—Concluded Mean Monthly Amount of Cloud at the Royal Observatory, Greenwich, for the Seventy Years 1818 to 1887, as referred to the Mean of Observations taken at 9h., 12h., 15h., and 21h., daily, with Means for Ten-Yearly Periods.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly Mean.
1818	7·4	6·9	7·3	7·1	6·0	5·0	6·2	6·1	6·4	6·0	7·1	7·2	6·56
1819	6·3	7·3	8·6	5·7	6·8	7·2	6·9	6·3	6·5	6·8	7·7	6·8	6·91
1820	7·5	7·6	6·5	5·7	6·3	7·3	7·7	5·8	5·7	6·3	7·9	9·0	6·94
1821	8·8	6·1	7·1	6·3	7·0	7·0	7·2	5·9	7·2	5·7	6·9	6·3	6·79
1822	7·4	5·2	6·0	6·6	4·8	4·7	7·1	5·8	5·7	6·6	5·6	5·7	5·93
1823	8·6	7·7	7·9	6·6	5·2	6·5	7·9	6·9	4·4	6·0	7·8	6·0	6·79
1824	6·6	7·5	8·0	6·2	7·5	7·2	6·7	6·9	5·8	6·8	6·9	6·2	6·86
1825	7·5	7·9	6·4	5·3	6·2	5·2	4·3	6·3	5·4	6·8	6·4	7·1	6·23
1826	6·3	6·7	6·3	6·5	6·3	4·2	5·8	4·7	5·7	6·1	6·3	7·7	6·05
1827	7·3	6·1	6·7	6·2	6·6	6·5	5·0	6·8	7·4	6·4	7·0	6·8	6·57
1828	7·9	7·3	6·6	7·7	6·1	5·8	7·4	6·5	5·1	5·2	6·3	7·2	6·59
1829	7·3	8·2	6·8	7·6	4·9	6·1	7·0	6·9	6·0	6·6	7·4	8·7	6·96
1830	8·9	7·3	5·2	6·1	6·1	7·8	6·7	6·2	6·3	6·0	5·1	6·9	6·55
1831	7·5	6·0	6·9	7·2	5·3	5·9	5·6	6·1	6·7	6·3	6·9	6·1	6·38
1832	7·1	6·8	6·8	5·3	6·4	7·1	6·2	6·3	4·5	6·5	6·8	6·8	6·38
1833	7·3	7·7	7·4	6·7	3·6	5·7	6·5	6·2	5·5	5·7	6·9	7·2	6·37
1834	7·0	6·3	6·1	5·7	4·1	5·0	6·5	5·9	5·5	4·6	7·5	6·4	5·88
1835	7·0	6·1	6·8	5·7	6·5	5·7	3·3	4·7	5·9	6·8	7·1	7·1	6·06
1836	7·1	6·7	7·0	7·6	3·8	7·1	5·7	6·2	7·3	6·9	7·0	7·9	6·69
1837	8·7	6·9	7·1	7·3	6·6	4·8	6·0	6·0	5·8	6·3	6·0	7·5	6·58
1838	7·7	7·4	6·2	7·1	5·7	7·3	7·0	6·6	6·4	7·1	7·4	7·4	6·94
1839	6·9	7·1	7·8	6·9	5·1	6·6	7·2	6·6	6·7	6·5	8·2	7·6	6·93
1840	6·3	7·4	6·2	3·7	6·5	6·6	7·8	5·3	6·2	5·6	5·7	6·8	6·17
1841	6·9	8·7	5·0	6·8	5·7	6·6	7·5	6·7	5·9	7·2	7·2	6·7	6·74
1842	7·8	7·3	7·4	4·6	6·0	4·7	6·0	5·0	6·7	6·4	7·5	7·1	6·38
1843	7·3	7·9	6·4	6·5	7·5	7·4	7·7	6·2	4·8	6·6	7·1	8·5	6·99
1844	7·5	6·7	7·2	4·1	6·5	6·1	7·1	6·4	6·1	6·8	8·3	8·5	6·77
1845	8·6	6·6	6·7	5·8	8·1	5·8	7·5	6·7	6·6	6·5	6·5	6·3	6·81
1846	7·8	7·7	7·0	7·8	6·7	4·9	6·9	7·8	6·1	8·1	7·4	6·8	7·08
1847	7·1	7·3	6·0	6·9	6·2	7·0	5·8	7·3	6·8	7·8	6·9	7·9	6·92
1848	8·1	7·7	7·9	7·4	3·0	7·4	6·6	7·6	5·6	7·3	6·7	6·7	6·83
1849	7·9	6·7	8·0	7·8	7·7	6·5	5·9	7·1	7·0	6·9	6·9	7·1	7·13
1850	8·4	7·3	6·8	8·2	7·4	4·7	7·9	7·4	7·4	7·2	7·1	8·2	7·33
1851	6·9	7·2	8·0	8·3	7·1	6·5	8·0	7·0	6·3	8·0	6·4	8·6	7·36
1852	6·2	6·8	6·3	5·0	8·0	8·6	4·8	6·8	6·9	7·0	8·4	7·9	6·89
1853	7·4	8·2	7·2	8·7	6·1	7·7	8·3	7·7	6·7	7·8	7·5	7·9	7·60
1854	8·0	6·4	6·1	4·7	6·9	8·2	7·3	6·8	4·2	6·4	7·3	5·9	6·52
1855	8·7	8·0	7·8	5·8	7·7	6·9	7·0	5·9	5·4	7·4	8·1	7·0	7·14
1856	7·6	8·4	8·0	6·8	8·1	6·9	7·1	6·2	6·7	7·3	7·4	7·4	7·32
1857	7·5	6·8	7·8	7·8	6·1	4·8	6·4	5·7	5·8	6·6	8·2	7·2	6·73
1858	5·6	5·1	5·4	6·2	7·0	5·2	6·9	5·2	7·1	6·6	7·0	7·7	6·25
1859	7·5	6·3	7·2	6·9	6·1	7·4	5·1	6·5	6·9	7·2	5·9	7·2	6·68
1860	6·9	6·5	7·5	7·0	6·5	7·9	8·3	8·3	7·4	6·8	7·9	7·9	7·41
1861	7·0	7·4	6·5	7·1	7·6	7·4	7·4	5·9	6·3	6·5	6·9	6·5	6·87
1862	7·8	8·5	8·9	7·3	8·3	7·8	7·2	6·9	7·7	7·1	7·3	7·5	7·69
1863	7·3	6·5	6·4	6·6	6·3	7·2	5·0	7·0	6·9	7·2	7·0	6·8	6·68
1864	6·8	7·8	6·9	5·6	6·3	7·0	6·4	5·3	6·2	6·8	6·5	7·9	6·63
1865	7·2	7·8	7·7	4·2	6·4	5·9	6·5	7·0	3·2	6·2	6·2	8·3	6·38

TABLE I.—*Continued.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly Mean.
1866	7·5	7·2	8·1	6·3	6·1	6·9	7·0	7·7	7·8	7·3	6·1	7·4	7·12
1867	7·3	7·7	7·9	7·4	6·6	6·1	7·0	6·2	6·3	6·5	6·9	7·9	6·98
1868	8·4	6·3	6·4	6·9	4·9	4·4	4·9	6·5	5·2	5·8	7·8	7·4	6·24
1869	7·2	7·2	7·7	6·1	7·4	6·3	5·7	5·9	6·6	5·5	6·4	6·5	6·54
1870	6·5	7·4	7·5	4·0	5·6	6·4	6·6	6·2	4·3	6·2	6·1	8·1	6·24
1871	8·0	7·8	5·7	7·1	5·6	8·0	6·8	3·9	6·8	5·9	5·9	6·8	6·52
1872	6·9	7·2	6·5	5·6	6·9	6·5	6·1	6·2	6·4	6·8	7·1	7·1	6·61
1873	6·9	9·2	6·5	6·5	7·0	7·2	6·0	6·3	5·6	6·9	7·4	7·2	6·89
1874	6·7	7·1	6·5	5·8	6·8	6·4	5·7	6·8	6·8	7·2	6·6	7·2	6·63
1875	7·4	7·8	7·8	5·7	6·0	6·5	7·5	6·9	5·7	7·8	8·1	7·9	7·09
1876	7·6	7·5	6·5	6·2	5·2	6·5	5·5	5·1	6·6	7·5	7·0	8·1	6·61
1877	6·8	7·4	7·2	8·4	7·1	5·0	7·0	7·0	6·5	6·3	6·1	7·1	6·83
1878	7·8	8·4	7·7	6·4	7·1	6·5	6·9	7·3	6·2	6·6	7·9	7·6	7·20
1879	7·8	8·8	6·8	7·9	7·0	7·7	8·5	7·2	6·7	7·1	6·9	7·6	7·50
1880	6·3	6·9	6·1	7·4	6·4	7·8	7·2	7·3	6·1	7·1	6·2	7·6	6·87
1881	6·8	8·5	5·9	6·7	5·4	6·6	6·1	7·4	7·1	6·1	7·4	7·1	6·76
1882	8·2	8·0	5·6	6·4	5·5	8·1	6·5	7·0	6·9	7·6	6·5	8·2	7·04
1883	7·2	6·7	5·6	6·4	6·3	6·7	7·5	6·3	6·1	7·2	5·9	8·0	6·66
1884	8·0	7·0	6·8	7·5	5·5	6·7	7·1	4·6	5·9	6·7	6·7	8·2	6·72
1885	7·9	7·3	6·3	5·9	6·8	5·5	5·4	6·9	6·8	7·7	7·7	7·0	6·77
1886	7·2	7·8	7·5	6·9	6·8	6·5	6·5	6·0	6·1	7·4	7·0	6·0	6·81
1887	7·6	6·2	6·8	5·8	7·8	5·0	4·6	5·7	7·7	6·7	7·1	7·0	6·50
Means 1818–1827.	7·37	6·90	7·08	6·22	6·27	6·08	6·48	6·15	6·02	6·35	6·96	6·88	6·56
Means 1828–1837.	7·58	6·93	6·67	6·69	5·34	6·10	6·09	6·10	5·86	6·09	6·70	7·18	6·44
Means 1838–1847.	7·39	7·41	6·59	6·02	6·40	6·30	7·05	6·46	6·23	6·86	7·22	7·36	6·77
Means 1848–1857.	7·67	7·35	7·39	7·05	6·81	6·82	6·93	6·82	6·20	7·19	7·40	7·39	7·08
Means 1858–1867.	7·09	7·08	7·25	6·46	6·72	6·88	6·68	6·60	6·58	6·82	6·77	7·51	6·87
Means 1868–1877.	7·24	7·49	6·83	6·23	6·25	6·32	6·18	6·08	6·05	6·59	6·85	7·34	6·62
Means 1878–1887.	7·48	7·56	6·51	6·73	6·46	6·71	6·63	6·57	6·56	7·02	6·93	7·43	6·88
Means 1818–1887.	7·40	7·25	6·90	6·49	6·32	6·46	6·58	6·40	6·21	6·70	6·98	7·30	6·75

this way any change of secular nature is better brought out. The mean values in the first two groups are in general somewhat smaller than those of the remaining groups, though not universally so. The period 1848-1857 seems to have been a cloudy one, and the period 1868-1877 a clear one. It is conceivable that there may have been small changes in the method of observing, or that slight error may have been introduced in the process of combining the separate series of observations. But admitting imperfection to some extent, the results will still indicate the broad features of the individual months at Greenwich, features which also should be generally true for a considerable portion of the adjacent country. In the march of the monthly values through the year two maxima and minima occur. For the different ten-yearly groups and for the complete period these are as follows :—

Period.	First Maximum.	First Minimum.	Second Maximum.	Second Minimum.
1818 to 1827 ...	January	June	July	September
1828 ,, 1837 ...	January	May	{June / August}	September
1838 ,, 1847 ...	February	April	July	September
1848 ,, 1857 ...	January	May	July	September
1858 ,, 1867 ...	December	April	June	September
1868 ,, 1877 ...	February	April	June	September
1878 ,, 1887 ...	February	May	June	September
1818 ,, 1887 ...	January	May	July	September

At Oxford[1], from observations made from 1850 to 1884, these epochs are December, April, June and September respectively.

The persistence of the occurrence of the second minimum in September on the average is noteworthy, although the same by no means follows in separate years. We see that Spring and Autumn are the least cloudy, and Summer and Winter the most cloudy periods of the year, the order being, beginning with the least cloudy period—Autumn, Spring, Summer, Winter.

The order of cloudiness of the different months, beginning with the least cloudy month, is, in the different periods, including also the Oxford results, as follows:—

Royal Observatory, Greenwich.								Oxford
1818–1827.	1828–1837.	1838–1847.	1848–1857.	1858–1867.	1868–1877.	1878–1887.	1818–1877.	1850–1884.
Sept.	May	April	Sept.	April	Sept.	May	Sept.	Sept.
June	Sept.	Sept.	May	Sept.	Aug.	March	May	Aug.
Aug.	July	June	Aug.	Aug.	July	Sept.	Aug.	April
April	Oct.	May	June	July	April	Aug.	June	May
May	Aug.	Aug.	July	May	May	July	April	July
Oct.	June	March	April	Nov.	June	June	July	June
July	March	Oct.	Oct.	Oct.	Oct.	April	Oct.	Nov.
Dec.	April	July	Feb.	June	March	Nov.	March	March
Feb.	Nov.	Nov.	March	Feb.	Nov.	Oct.	Nov.	Oct.
Nov.	Feb.	Dec.	Dec.	Jan.	Jan.	Dec.	Feb.	Feb.
March	Dec.	Jan.	Nov.	March	Dec.	Jan.	Dec.	Jan.
Jan.	Jan.	Feb.	Jan.	Dec.	Feb.	Feb.	Jan.	Dec.

[1] *Results of Meteorological Observations made at the Radcliffe Observatory, Oxford, in the year* 1884, p. 128.

In regard to variation of value in the same month of different years the least and greatest values in each month are given in the annexed Table:—

Month.	Least Value.	In what Year.	Greatest Value.	In what Year.	Difference between Extreme Values.
January	5·6	1858	8·9	1830	3·3
February	5·1	1858	9·2	1873	4·1
March	5·0	1841	8·9	1862	3·9
April	3·7	1840	8·7	1853	5·0
May	3·0	1848	8·3	1862	5·3
June	4·2	1826	8·6	1852	4·4
July	3·3	1835	8·5	1879	5·2
August	3·9	1871	8·3	1860	4·4
September	3·2	1865	7·8	1866	4·6
October	4·6	1834	8·1	1846	3·5
November.....	5·1	1830	8·4	1852	3·3
December.....	5·7	1822	9·0	1820	3·3

Of individual months the least cloudy month was 1848, May=3·0, and the most cloudy month 1873, February=9·2. The differences between extreme values in the same month of different years shown in the last column of the preceding table are sufficiently remarkable, and represent in every portion of the year and especially during the summer months a large variation of solar influence. Such variations must necessarily affect vegetation and agriculture in a very considerable degree, since months in which the numerical amount of cloud was small will naturally have been months of unusual sunshine.

Examining further the separate values for the different months as regards extreme values, I have selected in each year throughout the series all months which depart considerably either in defect or excess from the general monthly mean, and have arranged them in a tabular shape as follows (p. 191) :—

Examination of the accompanying table shows that years in which there were three or more months in which the amount of cloud was unusually small were 1822, 1823, 1825, 1826, 1831, 1834, 1835, 1840, 1842, 1852, 1854, 1858, 1868, 1871, 1876 and 1887, and that years in which, on the contrary, there were three or more months having an amount of cloud unusually large were 1843, 1846, 1849, 1850, 1851, 1852, 1853, 1855, 1856, 1860, 1862, 1866 and 1879. The year 1852 is characterised by having three months of very small amount of cloud and three months of very large amount of cloud. The years in which the amount of cloud in no one month departed widely from the average were 1838, 1867, 1872 and 1874, and those in which the deviation was excessive in either direction in one month only were 1818, 1833, 1847, 1861, 1863, 1864, 1873, 1878, 1881, 1885 and 1886. The years which taken as a whole have a small amount of cloud are 1822, 1825, 1826, 1834, 1835, 1840, 1868 and 1870, and those which have a large amount of cloud are 1850, 1851, 1853, 1856, 1860, 1862 and 1879.

Having referred to the relation of the amount of cloud to the amount of sunshine, it may be interesting to give, for comparison with the monthly values of amount of cloud, the number of hours of bright sunshine registered in each month at Greenwich since registration of this element was com—

Year.	Months in which the Amount of Cloud was	
	Unusually Small.	Unusually Large.
1818	June	
1819	January	March
1820		July, December
1821	February	January
1822	February, May, June, Nov. Dec.	
1823	May, September, December	January, July
1824	December	March, May
1825	April, June, July	
1826	January, June, August	
1827	February, July	September
1828	September, October	April
1829	May	April, December
1830	March, November	January, June
1831	February, May, December	
1832	April, September	
1833	May	
1834	May, June, October	
1835	February, July, August	
1836	May	April, September
1837	June	January
1838		
1839	May	November
1840	January, April, August, Oct. Nov.	July
1841	March	February
1842	April, June, August	
1843	September	May, July, December
1844	April	November, December
1845		January, May
1846	June	April, August, October
1847		October
1848	May	August
1849		March, April, May
1850	June	April, May, July, September
1851		March, April, July, October, Dec.
1852	January, April, July	May, June, November
1853		April, June, July, August, October
1854	April, September, December	June
1855		January, May, November
1856		February, March, May
1857	June	April, November
1858	January, Feb. March, June, Aug.	
1859	July, November	
1860		June, July, August, September
1861		May
1862		February, March, May, June, Sept.
1863	July	
1864	August	
1865	April, September	
1866		March, August, September
1867		
1868	May, June, July, September	
1869	October	May
1870	April, September	
1871	March, August, November	June
1872		
1873		February
1874		
1875		October, November
1876	May, July, August	
1877	June	April
1878		February
1879		February, April, June, July
1880	January	June
1881		February
1882	March	June
1883	March, November	
1884	August	April
1885	July	
1886	December	
1887	February, June, July	May, September

menced. Until the end of the year 1886 the results are those registered by the original instrument presented to the Royal Observatory by Mr. Campbell, but from the beginning of the year 1887 an instrument of the Campbell-Stokes pattern has been employed. At the time of the preparation of this account the difference, if any, between the records obtained by these two patterns of instrument had not been determined (though the materials exist for so doing), consequently only results to the end of the year 1886 have been included here. Observations were commenced with the original instrument in May of the year 1876, but only complete years are included in the following table (p. 193):—

In making comparison of the sunshine results with the results for cloud, different months cannot be compared together, but the values of sunshine for the same month in different years, as will be seen, generally accord with the corresponding values of cloud contained in Table I., that is to say, increased sunshine is accompanied by diminished cloud. Comparing together the proportion of sunshine in different months, it will be observed that the relative sunshine is greatest in the month of May, being then equal to 0·368, and least in December, 0·086. The months of May and September have nearly the same amount of cloud, 6·89 and 6·44 respectively, but the corresponding proportions of sunshine are 0·368 and 0·298. The greater proportion in May as compared with September will be explained by considering that the sun's altitude in May is so much greater, his mean altitude above the horizon at noon being in May=57°, and in September only=41°. And although the sun's altitude at noon is somewhat greater in June=62°, and in July=60°, than in May=57°, these months are also more cloudy, thus causing the month of May to be pre-eminent amongst the months as having the greatest relative sunshine, as well as an actual sunshine very nearly equal to that of June (remembering that June contains one day less than May), although the mean altitude of the sun at noon in May is 5° less. In the summer months attention may be drawn to the great variation of sunshine in the same month of different years.

In regard to the question of greater or less sunshine in the two halves of the solar year, I have in a former paper[1] dealt in a slight degree with this question, but now a longer series of observations is available. Dividing the year into two parts, taking the summer solstice as occurring at noon on June 21, and the winter solstice at midnight of December 20, which in ordinary years divides the year into two portions of 182½ days each, the following results are found:—

Period ending	Total Duration of bright Sunshine between Solstices.	
	Summer and Winter. hours.	Winter and Summer. hours.
1876, December... ...	710·5	
1877, June		566·9

(Continued on page 194.)

[1] "On the Greenwich Sunshine Records 1876-1880," contained in the *Quarterly Journal of the Royal Meteorological Society*. Vol. VI. page 126.

TABLE II.—Number of Hours of Bright Sunshine recorded at the Royal Observatory, Greenwich, in each Month of the Ten Years 1877–1886.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	The Year.
	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.	h.
1877	18·7	36·4	99·3	71·8	147·1	267·1	177·2	158·6	105·6	101·1	56·6	27·0	1266·5
1878	35·0	32·9	73·1	150·4	166·0	183·4	163·9	160·0	127·5	100·8	40·5	16·3	1249·8
1879	14·8	31·7	91·0	74·6	135·6	141·9	99·3	139·1	116·5	66·7	43·2	28·4	982·8
1880	42·3	52·6	141·0	132·5	192·8	132·5	169·2	106·3	119·3	52·3	54·3	19·2	1214·3
1881	31·8	26·1	115·8	126·1	202·2	185·7	211·5	140·1	73·8	96·6	55·2	36·1	1301·0
1882	15·8	36·0	127·9	151·4	237·8	121·4	194·7	126·3	99·4	60·1	56·1	18·1	1245·0
1883	34·4	48·6	118·4	133·0	178·1	163·5	148·7	156·8	116·1	69·9	61·2	12·1	1240·8
1884	16·6	46·3	85·8	87·9	183·7	134·3	126·5	203·4	119·1	59·3	38·6	13·3	1114·8
1885	16·9	37·8	105·7	160·1	171·9	212·2	217·7	128·8	96·5	60·0	31·3	22·0	1260·9
1886	36·3	27·1	73·2	121·6	159·8	213·0	192·5	165·9	131·6	63·1	29·3	15·8	1229·2
Mean	h. 26·3	h. 37·6	h. 103·1	h. 120·9	h. 177·5	h. 175·5	h. 170·1	h. 148·5	h. 110·5	h. 73·0	h. 46·6	h. 20·8	h. 1210·5
Sun above horizon	h. 259·1	h. 280·1	h. 366·9	h. 414·9	h. 482·1	h. 494·5	h. 496·8	h. 449·1	h. 376·9	h. 328·7	h. 264·4	h. 242·7	h. 4456·2
Proportion of Sunshine } Constant Sunshine = 1 }	0·102	0·134	0·281	0·291	0·368	0·355	0·342	0·331	0·293	0·222	0·176	0·086	0·272
Mean Altitude of the Sun } at Noon ..... }	° 18	° 26	° 37	° 48	° 57	° 62	° 60	° 52	° 41	° 30	° 20	° 16	° 39
Corresponding Mean } Amount of Cloud }	7·40	7·68	6·55	6·99	6·39	6·71	6·87	6·70	6·44	6·98	6·83	7·44	6·91

Period ending	Total Duration of bright Sunshine between Solstices. Summer and Winter. hours.	Winter and Summer. hours.
1877, December... ...	685·0	
1878, June		565·6
1878, December... ...	690·9	
1879, June		447·3
1879, December... ...	588·8	
1880, June		647·6
1880, December... ...	561·8	
1881, June		639·6
1881, December... ...	673·1	
1882, June		658·3
1882, December... ...	585·1	
1883, June		635·7
1883, December... ...	609·2	
1884, June		487·1
1884, December... ...	627·0	
1885, June		656·9
1885, December... ...	604·0	
1886, June		550·4
1886, December... ...	676·0	
Means... ...	632·9	584·9

In the preceding comparison the observations of the year 1876 have been employed. There would appear to be a sensible preponderance in the amount of sunshine in the second half of the year, although this is not entirely supported in individual years. A yet longer series of observations would seem to be necessary before any definite conclusion can be drawn.

Having considered the monthly values of cloud and their relation to sunshine, we may now turn our attention to the diurnal variation of cloud. The two-hourly means in each month, formed from two-hourly observations made at the even hours of Göttingen time throughout each month of the years 1841 to 1847 (excepting on Sunday and a few other days), on which the values of cloud in Series II. depend, are as follows, substituting Greenwich civil time for Göttingen time (Table III. p. 195):—

We here see how small is the variation in the amount of cloud throughout the day in the months of January, February, November, and December; how large it becomes in March, continuing then large until September, the variation in October being intermediate in value. On the average of the whole year the sky is most cloudy at 11h. 20m. and least cloudy at 21h. 20m., the numbers being 7·15 and 6·05 respectively. The evening minimum appears to occur somewhat later in summer than in winter.

It seemed desirable to apply the harmonic formula to the diurnal variation

TABLE III.—Mean Amount of Cloud at the Royal Observatory, Greenwich, at each of the Twelve Hours of Observation during the Period 1841 to 1847.

Greenwich Civil Time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Means.
h. m.													
1 20	7·34	7·51	6·31	5·43	6·11	5·37	6·46	5·84	5·16	6·41	7·51	7·49	6·41
3 20	7·33	7·64	6·47	5·89	6·59	5·99	6·93	6·53	5·57	6·94	7·43	7·67	6·75
5 20	7·24	7·64	6·30	6·19	6·66	5·90	6·99	6·73	6·63	6·93	7·51	7·44	6·85
7 20	7·50	7·70	6·47	6·00	6·76	5·87	6·67	6·89	6·74	6·81	7·57	7·73	6·89
9 20	7·86	7·37	6·47	6·81	6·83	6·41	7·33	7·09	6·66	7·14	7·61	7·39	7·08
11 20	7·81	7·37	7·01	6·30	7·34	6·29	7·60	7·21	6·83	7·29	7·37	7·33	7·15
13 20	7·83	7·53	7·01	6·24	7·17	6·20	7·56	6·91	6·44	7·36	7·50	7·50	7·10
15 20	7·69	7·41	7·13	6·31	6·99	6·11	7·14	6·56	6·24	7·64	7·34	7·39	7·00
17 20	7·63	7·53	6·51	5·90	6·21	5·80	6·43	6·14	5·60	7·11	7·30	7·17	6·61
19 20	7·43	7·33	5·63	5·50	5·79	5·39	6·10	5·84	5·51	6·33	6·61	7·47	6·24
21 20	7·50	7·49	5·44	4·97	5·71	5·44	5·84	5·31	5·07	6·04	6·73	7·03	6·05
23 20	7·76	7·37	5·74	5·47	5·57	5·57	5·70	5·50	4·76	6·07	6·96	7·36	6·15
Means	7·58	7·49	6·37	5·92	6·48	5·86	6·73	6·38	5·93	6·84	7·29	7·41	6·69

of cloud given in the preceding table, and the coefficients and constant angles have therefore been calculated for a few terms of the harmonic expression $C = M + a.\sin(\alpha+t) + b.\sin(\beta+2t) + c.\sin(\gamma+3t) + \&c.$, for each month and for the year, C representing the observed amount of cloud at the time t. If t be reckoned from mean midnight, the constant angles are α, β, γ, but if reckoned from apparent midnight, the constant angles are $\alpha_1, \beta_1, \gamma_1$.

TABLE IV.—Co-efficients and Constant Angles in the Harmonic Formula for the Diurnal Variation of Cloud.

C	M	a	α	α_1	b	β	β_1	c	γ	γ_1
			°	°		°	°		°	°
January	7·58	·204	244·8	247·2	·166	115·0	119·8	·077	85·6	92·8
February	7·49	·093	11·7	15·2	·091	308·4	315·4	·048	180·8	191·3
March ..	6·37	·587	281·8	283·9	·423	13·3	17·5	·098	53·1	59·4
April	5·92	·615	293·7	293·7	·113	338·9	338·9	·124	36·9	36·9
May ..	6·48	·742	292 6	291·7	·256	15·7	13·9	·093	255·7	253·0
June	5·86	·437	290·6	290·7	·087	41·4	41·6	·021	318·4	318·7
July	6·73	·776	293·2	294·6	·310	21·7	24·5	·189	291·4	295·6
August ..	6·38	·843	301·2	302·1	·132	341·2	343·0	·107	310·8	313·5
September	5·93	·959	296·9	295·6	·187	263·8	261·2	·123	223·3	219·4
October ..	6·84	·600	275·3	271·8	·343	348·8	341·8	·055	23·1	12·6
November	7·29	·373	324·4	320·8	·188	5·6	358·4	·137	64·1	53·3
December	7·41	·159	353·0	352·0	·085	337·2	335·2	·013	37·1	34·1
The Year	6·69	·506	294·4	294·4	·152	2·1	2·1	·024	345·0	345·0

The coefficients a, b, and c all have in general small values in winter and larger values in other parts of the year. The analysis seems to bring out no other particular feature.

The cloud results which I have here put together might be compared with other meteorological elements, as temperature, &c., but into such discussion I cannot enter here. I had for some time been desirous of bringing together

and endeavouring to combine into one series the various existing Greenwich observations of cloud, and having, with this object in view, some time ago made, as already mentioned, a certain progress in the work, I resolved if possible to incorporate the results in this address. I have discussed the observations in such manner as seemed to me best, and trust that the results presented may be found to possess some degree of interest.

In the two addresses to which you have done me the honour to listen, I fear that Meteorology will sometimes appear to have occupied only a secondary place, and that in its name I have taken the opportunity to speak much of other things. But this may not be altogether an evil. A former President told you that his meteorology had a strong geographical bias. Mine, I suppose, has an astronomical one, equally strong. That of my successor, again, may prove to be of quite another complexion. This variety is in itself beneficial, and indeed strikingly illustrates the intimate relation existing between meteorology and other branches of science. If, however, I have on either of the two occasions shown myself in some degree discursive, I can at least claim to have found my way home in the discussion to which I have just drawn your attention.

One concluding word. In science the advance made in recent years has been in every direction great, and the spirit of inquiry in our day meets with many noble rewards. Our own science of meteorology did at one time appear likely to form in some degree an exception to the general rule, for more perhaps than any other it requires for its proper pursuit that which it is so difficult to obtain, the united action of many workers, without which the study of atmospheric conditions and changes cannot be carried on in any sufficiently complete and satisfactory manner. The field of inquiry which we of this generation have seen opened out has enabled us to study meteorological questions in a way never before possible. We already talk of the New Meteorology and of Modern Meteorology, phrases typical of the advance in recent years achieved. But much remains to be done. If we could further extend our sphere of observation, what might not be at no very distant date accomplished. And that with Meteorology our Society may prosper in the future as it has done in the immediate past, will, I am sure, be the hearty wish of all the Fellows thereof.

ON ATMOSPHERIC ELECTRICITY.

An Address delivered at the Meeting of the Royal Meteorological Society, March 21st, 1888.

By W. MARCET, M.D., F.R.S., President.

It is in no way remarkable that bright flashes of lightning, with their accompanying peals of thunder and enormous destructive power, should have been objects of awe and wonder at remote periods. The Etruscans took much interest in all that related to storms, and in a most mysterious way pretended to draw down lightning flashes in the name of Jupiter Elicius. The Romans acquired these rites from the Etruscans, and Tullus Hostilius, successor of Numa, wishing to practise the magic art of controlling the great electric displays of nature, was punished for his temerity and killed by lightning. The belief in fulgural science lasted a number of centuries, and Constantine the Great, even after he had become a Christian, made a law authorising the Romans to consult the Auspices whenever a building was struck by lightning.

It seems that no true knowledge existed of atmospheric electricity till the 18th century, when Dr. Wall having produced for the first time the electric spark, compared it to thunder (lightning); but he did not pursue the subject.

Franklin in America in 1752 entertained the bold idea of seeking for electricity in the very midst of the clouds. With this object he made use of a kite, and succeeded in drawing a bright spark from the string which held it. The experiment was made about the same time in Europe, and M. de Romas having led a wire down the whole length of the twine to which his kite was attached, obtained sparks nine or ten feet in length, which were accompanied by loud reports. Notwithstanding the many precautions he had taken to insulate his apparatus, de Romas was on one occasion struck down, though not killed, by the violence of a shock he accidentally received.

Lemonnier was the first to prove, by means of insulated metal rods, that, even in fine weather, the atmosphere is charged with electricity; but the two philosophers who laboured most actively in the present field of research, about the end of the last century, were unquestionably de Saussure and Volta. They constructed instruments called electroscopes, with the view of collecting atmospheric electricity and making apparent its effects; the collecting portion of the instrument being an iron rod capable of elongation, which, in de Saussure's instrument, conducted the electricity of the air in contact with the upper end of the rod to two little pith balls suspended by fine wires and placed in a glass case, so that the electricity conducted from the rod to these pith balls caused them to diverge from each other.

Volta substituted for the wires and pith balls two blades of straw about

two inches in length, the instrument being more sensitive than de Saussure's.

However, of all electroscopes, the most delicate is that made with gold leaf; but before entering further into the subject of electroscopes and electrometers, of which I shall have but little more to say, I must beg to give the uninitiated a few hints on the general laws of electricity, otherwise I fear some of my audience may not be able to understand clearly the remarks I have to offer about the wild and grand displays of the electrical phenomena of storms.

Like *heat*, electricity is the manifestation of a peculiar condition of a body, and bodies are said to be *electrified* when, after having been rubbed, or placed in communication with an electrified object, they exercise an attraction or repulsion, more or less great, upon other light bodies. On inquiring into this phenomenon, it is found that the *electricity* developed by friction from different substances, such as *glass* on one hand, and *sealing-wax* on the other, is not identical, and that there are consequently two electricities varying from each other in some of their characters. It may be said in a general way—

1. That there is an attraction between an electrified body and another not electrified.

2. That there is an attraction between two bodies electrified—the one by a rubbed glass rod, the other by a rubbed stick of sealing wax, or of some resinous substance.

3. That there is a repulsion between two bodies, both of which are electrified either by glass or by sealing wax.

To put these laws of nature more clearly—electricities of different kinds attract each other, and electricities of the same kind repel each other.

In order to distinguish between the two kinds of electricity, the one is called *vitreous* electricity from its being generated from glass, and is known as *positive*, while the other is called *resinous* electricity, and is known as *negative*.

You will now understand the principle on which *electroscopes* are constructed. In the gold-leaf electroscope electricity is made to act through a metal rod upon two gold leaves suspended to the end of the rod and closely applied to each other; both leaves, being brought under the influence of the same kind of electricity, will of course diverge or repel each other.

The method of electrifying may vary, indeed it is not necessary to touch with the electrifying body the metal rod carrying the gold leaves. No more need be done than bring the electrifying body near the rod, and the gold leaves will at once diverge.

The earliest instrument for measuring the *intensity* of electricity, which instrument is called an *electrometer*, is known as Coulomb's Torsion Balance, which you will see in our exhibition; by this means one of the principal laws of electricity was discovered—that two electrified bodies, whose size is very small in comparison with their distance apart, attract or repel each other with a force proportional to the inverse square of the distance which separates them.

Sir William Thomson's electrometer may be considered as the best means we possess of measuring the degree of atmospheric electricity; the most interesting part of this instrument is the method adopted for collecting the electricity from the air. Instead of a metal rod, as in de Saussure's and Volta's instruments, a water dropping collector is used, it consists of a small water cistern supported on glass legs so as to insulate it, or in other words to prevent the electricity it acquires from escaping into adjacent bodies. A small tube from the cistern lets out the water drop by drop. As soon as a drop forms it becomes covered with electricity taken from the air in contact with the drop; this electricity immediately runs into the cistern, where it is stored up, and each drop sends in a fresh supply of electricity to the cistern, which is in direct communication with the portion of the instrument registering the electric force.

There is another point to which I must beg to call your attention. As soon as an insulated object, say a metal conductor, is touched by an electrifying body, the conductor is instantly electrified throughout; thus a flash of lightning striking a metallic conductor will go through its whole length almost instantly. Moreover, the form of a body is greatly concerned in electric phenomena, thus atmospheric electricity will pass very readily into pointed metallic rods, and equally rapidly out of such rods into the atmosphere. This is the explanation of the hissing sound heard from pointed metal conductors during a thunderstorm. A friend I often meet at the Alpine Club was telling me recently of his experience on the Matterhorn in stormy weather, when on holding his ice-axe upwards by the wooden handle it began to emit a loud hissing sound. His guide advised him to put the axe under his arm, but he did not quite like that idea.[1]

As a rule, electricity is formed or developed in bodies by heat, friction, or chemical action, but none of these fully account for its presence in the atmosphere. It is thought by the distinguished physicist M. de la Rive that the positive electricity of the air is derived mainly from the sea. Becquerel has observed that sea-water is always possessed of positive electricity, and according to Peltier land is always negative in its electrical character. Hence the stratum of air in contact with the sea is invariably positive, and remains so while rising in space; the terrestrial negative reaction being weaker is quickly overcome by the more powerful positive condition of the atmosphere, and air exhibits, as a rule, positive characteristics.

An electric reaction, or, in other words, a state of electric tension, is always to be met with in the atmosphere, whether clear or cloudy. Electricity

[1] Popular notions are occasionally somewhat singular. Some years ago, on my being out fish spearing at night in the Mediterranean, a torpedo ray was caught; as it was dark I did not recognise the fish, and took hold of it to put it in the light of the brasier burning in a grate in the bows of the boat. I received at once a violent electric discharge, to the great amusement of the fishermen. One of them told me to bite one of the fingers of my left hand very hard, when I would be able to handle the fish with impunity. This advice was not given in a jesting way, but, as you may anticipate, I did not act upon it.

under a clear sky is almost constantly positive, and its potential, or intensity, becomes greater at increasing altitudes. This was observed by de Saussure and Ermann; and more recently Quetelet and Sir William Thomson have added to our knowledge of the subject by careful inquiries. Sir William Thomson found, on one occasion, the potential in the island of Arran to increase from 28 to 46 volts for a rise of one foot in level, but the difference was sometimes 8 or 10 times as much, changing rapidly as the East wind blew masses of clouds charged with positive or negative electricity across the sky.

Many observatories now keep continuous records of atmospheric electricity, but the observations do not appear to admit of comparison between one station and another. It is an important condition with reference to such observations that there be no elevated spots towering over or in the immediate neighbourhood of the place where they are carried on, and of all stations the Peak of Teneriffe, rising to an altitude of 12,200 feet in Mid-Atlantic, certainly appears particularly suited for testing the electrical conditions of the atmosphere. At our meeting of the 15th February the Hon. Ralph Abercromby communicated the very interesting observations made on that Peak which are in our immediate recollection. He told us that every experiment showed *positive* electricity of variable potential. At Puerto d'Orotava, Teneriffe, at the seaside, the mean observed was 188 volts, while on the summit of the Peak, with no objects above it far or near, the potential rose to no less than 549 volts, wind North-east, no upper clouds visible.

The great dryness of the air on the Peak of Teneriffe is probably not unconnected with a display of electrical phenomena of a peculiar kind. Thus, when in July and August, 1878, I spent three weeks on that same Peak, engaged with an inquiry mostly of a physiological nature; at an altitude of 7,000 feet, I observed at night inside the tent bright electric flashes, which were best produced by rubbing with the hand the surface of a mackintosh coat; on rubbing the sheets inside our beds, both I and a Chamounix guide, my companion, obtained similar electrical effects. The air was then very dry, so much so that in the daytime there were over 30° between the readings of the dry and wet bulb thermometers. The leather of our boots tore and split, boxes of instruments cracked, and the wood contracting, large rents appeared in them. We were unconscious of perspiration, owing to the rapid evaporation of the skin, though under a temperature which, from Piazzi Smyth's estimation from observations made with the black bulb *in vacuo*, probably rose to 212° F., or the boiling point of water at the seaside. Our skin, especially about the hands, became scaly from dryness, the slightest wound such as a minute cut or a prick would not heal, and my companion, who had to do the cooking and washing up, was much tormented on that account.

In the very dry weather of a Canadian winter similar effects are observed; for instance, after rubbing the feet briskly on the carpet it is found that if a gas jet for instance be touched with the finger, a spark will fly between the finger and the metal burner, kindling the gas if not lighted; this, surprising as it appears, is I understand, a common experiment with our Canadian friends.

The effects of atmospheric electricity may show themselves under three distinct forms—

1. Lightning in thunderstorms.
2. The formation of hail.
3. The formation of the Aurora Borealis and Australis.

I must now tell you how clouds acquire their electrical activity. Supposing in a blue sky a cloud forms owing to a local condensation of moisture, it becomes immediately charged with positive electricity from the air. Under ordinary circumstances a number of clouds so charged would produce no electric action, beyond an influence tending to keep them apart from each other; but let heavy, dark clouds rise from below nearer to the earth, filled with terrestrial negative electricity, then as soon as they approach the higher positive clouds the two systems of clouds attract each other and discharge their electricity, giving rise to flashes of lightning. In order to explain the enormous electric tension, or power, which a single cloud often displays in a storm, it is assumed that the positive electricities possessed by every particle of vapour in clouds accumulate in the globule formed by the union of several of these particles, so that a storm cloud must be considered as an aggregation of distinct bodies all having electrical power. When lightning occurs, the surface electricity of a cloud, alone, is liberated, but this same cloud-surface instantly derives fresh electrical power from the electricity condensed within it, thus several flashes can be given out in rapid succession from the same cloud.

Storm clouds show certain distinctive features. They generally appear at some point of the horizon—black and threatening; they increase in size and extend, rising slowly, though always appearing attached to that part of the land where they first originated. From the highest portion of this dark compact mass another system of clouds is observed to issue, under the form of long streaks, which though still connected with the parent formation, cover the whole sky. Independently of those streaks, lighter clouds are observed here and there in the atmosphere, which Beccaria has called "*ascitizi*," or additional clouds. It may be added that this dense cloud formation, which appears perfectly smooth at its lower surface, presents on its upper high protuberances and deep depressions, when viewed from some elevated station above the storm.

As to the height of storm-clouds, it follows from the observations of Humboldt, de Saussure and many others, in the Andes, Alps and Pyrenees, that there are frequent storms at immense heights, and Glaisher in one of his balloon ascents[1] observed *nimbi* or rain-clouds at an altitude exceeding 4 miles or 21,000 feet. There is, on the other hand, an instance on record of a storm-cloud attended with lightning only 26 feet in thickness and 100 feet in elevation above the ground; this was, it is true, an extreme case, as in general the altitude of such clouds varies between 650 and 6,500 feet.

When storm-clouds, charged with contrary electricities, approach each

[1] *Travels in the Air.*

other, sparks commence to pass between them even at great distances; shortly afterwards the electric attractions and repulsions, in addition to the action of the wind, bring the clouds near to each other, often giving them the most fantastic forms, and then lightning in rapid succession illuminates the sky whilst roaring thunder is heard far and wide.

When a storm-cloud charged with positive electricity comes within a certain distance of the earth, the negative electricity the latter contains is brought into a state of high tension, and then the two electricities fly towards one another and meet in the form of a flash which has apparently struck the earth; but it has just as well struck the cloud, only there is nothing in the cloud to sustain any damage, while on the earth there are many objects a flash might destroy, to say nothing of its fatal effects upon animal life.

Thunder is the noise produced from air rushing in to fill up the vacuum produced by the enormous expansion due to the heat of the lightning-flash; this is productive of a violent state of vibration. Those who have met with a storm in mountains must have observed the magnificent effect of the echo as the thunder clap rebounds from one mountain to another.

Lightning may issue not only from clouds but also from volcanoes in an active state. The eruption of Vesuvius, in 1794, described by Hamilton, was accompanied by storm-clouds, which sent forth lightning emitting a noise comparable to the loudest claps of thunder; this volcanic phenomenon was in every way similar to a common thunderstorm, one cloud in particular, consisting mostly of fine ashes, was carried by the wind over the city of Tarento, 248 miles distant from Vesuvius, and then discharged a flash which struck a house. Recent inquiries by Professor Palmieri have thrown much light on the electrical phenomena of volcanoes.

A long series of observations has shown that there exists a certain distribution of storms on the surface of the globe, changing with the seasons. According to Arago's researches, Jamaica is particularly liable to thunderstorms. From the first day of November to the middle of April the mountains of Port Royal daily become covered with clouds between 11 o'clock and noon. At one o'clock they assume a dark threatening aspect, then rain pours down in torrents, and lightning flashes in all directions, attended with loud peals of thunder; but the storm is soon over, and by about half-past two the sky has entirely cleared up. This phenomenon recurs every day, or nearly so, for five months in succession.

The speed of lightning is very great, and Wheatstone has shown that the time a flash lasts is less than the thousandth part of a second, while it is stated in Mr. Scott's excellent book on Meteorology that an electric spark 0·1 inch in length has been found by the same distinguished electrician to last about the $\frac{1}{14000}$ part of a second. An idea of the brief duration of an electric spark can be formed by giving a rapid rotatory movement to a disc marked with coloured rays from rim to centre; with ordinary light the rays are not distinguishable, and the disc assumes an uniform colour, but when lighted up by an electric spark the duration of the light is so instantaneous that the

coloured sectors have no time to move from one spot to another while the light lasts, and therefore appear at a standstill.

Photographs of lightning have been recently obtained, which may certainly be called triumphs of photography; it is indeed wonderful that there should be a chemical substance so sensitive to light, that an exposure lasting less than a thousandth part of a second should suffice to alter its composition. The taking of such photographs is attended, I understand, with no particular difficulty, but must be done at night. The uncovered lens of the camera is turned towards a cloud giving out flashes of lightning, and as soon as one or more flashes have occurred within the field of view of the instrument, the lens is covered and the plate removed. Several flashes can be taken on the same plate. You will see very fine photographs of lightning in our exhibition; some of them have been enlarged for the occasion, giving thereby a more striking effect.

Lightning may be divided into three classes, 1st, zigzag or forked lightning, 2nd, diffused or sheet lightning, and 3rd, globular lightning. You will observe in the lightning photographs of our exhibition how a zigzag flash often branches off into several subsidiary flashes; the track of the spark is most erratic as it makes its way through the channel of least resistance, which accounts for its erratic course; some flashes are seen in the photographs to dart between cloud and cloud, others between cloud and earth.

Sheet lightning, instead of being concentrated into wavy tracts, is wider and less bright; its colour is often of an intense red, sometimes it is blue or violet, and lightning of this kind may be actually invisible, though illuminating a whole cloud, at other times giving it a bright fringe. The phenomenon called heat lightning appears as distant luminous flashes, and proceeds from a storm below the visible horizon. A parallel instance is that of the light of a house on fire, which can be seen at a very great distance because of its being reflected from the sky just above the seat of the conflagration.

Lightning of the third class differs from the others in respect to form, velocity and duration; it is visible for 1, 2, or even 10 seconds, and its movement can be distinctly followed with the eye; from its spherical form it has been called ball-lightning. These electrical phenomena are indeed true globes of fire, sometimes dividing or bounding over the earth again and again. They may burst with a terrible report, in some cases shooting out rays of forked lightning in all directions. Such globes of fire have been seen of the size of a child's head and comparable to the full moon travelling slowly along the ground. Mr. Scott quotes from Arago's Meteorological Essays several instances of globular lightning. Thus at Milan in 1841 one of these globes moved along a street so slowly that people walked after it; a few minutes later it struck the cross of a church-steeple and disappeared. Again in Paris a fire ball, was seen descending from the sky increasing in size, and then bursting with a terrible explosion, darting from it ten or twelve forked flashes which shot forth in all directions; one of these struck a neighbouring house, where it made a hole in the wall as if it were a cannon ball. Again, quoting from our own Journal, Dr. Tripe reported

that in 1874, in a fearful storm of hail, rain, wind and lightning, he saw a large ball of fire rise apparently about a mile distant from him from behind some low houses. The ball at first rose slowly, but moved quicker as it ascended; when at about 45° it started off at an acute angle from South to West with such great rapidity as to produce the appearance of forked lightning; it made three zigzags before entering a dark cloud.

Another instance of a remarkable kind is recorded by Mr. M. Fitzgerald as having occurred in the Glendowan Mountains in Ireland. He noticed a globe of fire in the air floating leisurely along, it descended from a ridge into the valley and reached a stream about 300 yards from the spot where the observer stood. It then struck the land and reappeared in about a minute, again disappearing and reappearing several times, until it flew across the stream and finally lodged in the opposite bank, leaving a hole where it had buried itself. On examination of the track of this meteor, an aperture about 20 feet square was found in the peat where it had first touched the land, with the peat turned up on the lea as if it had been cut with a huge knife; it next made a trench about 20 perches in length and 4 feet deep, afterwards ploughing up the surface to about a foot. Next it tore away the bank of the stream about 5 perches in length and 5 feet deep, and then hurling the immense mass into the bed of the stream flew into the opposite peaty soil. From its first appearance till it buried itself could not have been less than twenty minutes, during which it travelled leisurely as if floating with an undulatory motion through air and land over a mile. It appeared at first as a bright red ball of fire about 2 feet in diameter, but became rapidly smaller, particularly after each dip in the soil, so that it looked not more than 8 inches in diameter when it finally vanished.

I have myself witnessed a similar phenomenon some years ago, though of a much briefer duration. Being on my way in a pony-chaise from Esher station to a house near Claygate, during a thunder-storm, rain pouring heavily, I was crossing the Esher Common, the road leading in the direction of a hedge. When perhaps about 10 yards distant I saw a fire-ball on the hedge; the phenomenon was also witnessed by a person with me in the carriage, and the pony alarmed stopped short; the occurrence lasted perhaps a second. The next day I examined the place, but could find nothing unusual in the hedge.

I must not omit to allude to the counter-shock or return-stroke produced on the earth when a cloud, after inducing an electrical charge on the earth's surface immediately under it, either discharges its electricity to another cloud or is wafted away by the wind. The two electricities occasionally suddenly unite, attended with fatal effects if a person or an animal should accidentally be on the spot.

With reference to the effects of the discharges of atmospheric electricity there are so many extraordinary accounts of steeples, houses, trees, ships, and other objects struck by lightning, that it would take me much too long to recall all those I have met with. It is remarkable what a very limited area may be included in a flash of lightning, thus you will see in our

hibition clothes torn into rags by lightning, whilst the man who was wearing them was apparently not seriously hurt, this interesting exhibit being kindly lent us by the Royal College of Surgeons. I find similar instances given by Mr. Symons in the *Report of the Lightning Rod Conference*. Thus on August 18th, 1858, near Norwich, a boy riding on a pony escaped unhurt, the pony being killed by lightning. In the New Kent Road, whilst a man was sawing wood, the lightning entered by the window, struck the blade of the saw, burnt the handle, but did not injure the man. It is also remarkable that a small object perfectly insulated from the ground should not be safe from lightning, thus on October 11th, 1858, at Witham, Yorkshire, two sea-gulls, while flying, were killed by lightning. De la Rive quotes the remarkable instance of a lady who, wearing a gold bracelet, was holding her hand out of a window, had the bracelet destroyed by the lightning, and yet felt no more than a very slight shock. Another lady, under similar circumstances, had her bonnet entirely burnt on account of the wire its frame was made of, but she was uninjured.

My only personal observation is the curious fact of a chestnut tree in a small wood on the Savoy coast of the Lake of Geneva being struck twice by lightning in the short space of four days. On the first occasion a deep fissure was produced along the trunk of the tree, on the second, the tree's head was cut off. That tree was not taller than the others, and I could find no dampness in the soil at that spot; why it should have been so selected by the electric discharge is most unaccountable.

I do not propose to enter into other effects of lightning, interesting as they unquestionably are, such as the production of certain long tubes called fulgurites, of which we have some remarkable drawings in our exhibition, but I must now show you a lightning flash; although not coming from a cloud it will have absolutely all the characteristics of a real lightning flash. You will see first of all sheet lightning and then a vivid flash of forked lightning, with its zigzag course most perfectly reproduced. You will observe that the form of the zigzag varies more or less with every flash, which is 6 or 8 feet in length. This experiment, which I have never seen or heard of before, and is therefore original as far as I know, simply consists in throwing the image of a spark from a powerful electric machine upon a white screen, after magnifying it by the aid of an optical lantern.

The following are a few remarks on Lightning Conductors:—In 1882 a Lightning Rod Conference was held by delegates from this and various Scientific Societies, and a very important and interesting Report was subsequently drawn up. A lightning rod, by offering a free channel to the electric current, is, when erected under proper conditions, an effectual protection against lightning to the house or building on which it is placed. Besides discharging atmospheric electricity to the earth, conductors tend to prevent sudden discharges by silently neutralising the state of electric tension to which such discharges are due.

Iron and copper are practically the only two metals used; the rods may be circular or flattened into tapes. A copper rope should not be less than

½ inch in section, and an iron rod 9-10ths of an inch in diameter, but the reliable protection from a lightning conductor depends mainly upon its mode of connection with the earth. The conductor, in order to transmit freely the lightning flash to the earth, should terminate as often as possible in water, such as a well or water tank; next best in moist earth. The Lightning Rod Conference recommends soldering to the earth end of a conductor a plate of metal of the same kind as the conductor, and burying this plate in a hole so deep that the earth surrounding it shall never be dry. It is frequently entirely to the neglect of these conditions that failure in the proper action of such conductors is owing.

Atmospheric electricity is concerned in the formation of hail. Hail stones vary in size and shape; showers of sleet are not uncommon, and under certain peculiar conditions of the atmosphere, a particle of sleet becomes the nucleus of a hail stone round which are disposed concentric frozen layers, some of clear and others of opaque ice; two or three layers are often distinctly seen; from this circumstance it may be surmised that each layer has been formed under different physical conditions, just as an absence of distinct layers would seem to point to a single and uniform cause of enlargement. The size of hail stones varies up to that of a pigeon's or hen's egg. Hail stones have no definite shape, some are rounded, others elongated; at times they are egg-shaped, pyramidal or conical. They are occasionally studded with crystals standing out on their surface. You will see in our exhibition some remarkable drawings of hail stones, enlarged by photography.

The formation of hail requires the following conditions:—1st. A large accession of moisture. 2nd. A temperature below freezing point. And 3rd. The presence of electrified clouds. The fall of temperature in storm-clouds giving rise to hail, is considered as due to a sudden reduction of vapour tension, and Prof. Colladon of Geneva has propounded an ingenious and plausible theory to account for such a phenomenon. According to this distinguished physicist, the heavy rainfall preceding a hail shower carries a mass of air before it and causes a strong downward current; this is obviously attended with a powerful suction or a partial vacuum in the upper clouds. At once a fall of temperature takes place which causes a condensation of moisture into frozen particles.

The down draft from the shower of rain preceding a hail storm is productive according to M. Colladon, of upward and side currents of air which drive up these particles and tear the rain cloud into a number of separate cloud masses each of them powerfully electrified; the particles of frozen moisture are now attracted and repelled between these cold clouds while driven about by the wind, thus increasing rapidly in size until they become so heavy that they fall to the ground in the form of hail.

The disastrous effects of a hail storm, especially in wine growing countries can hardly be imagined, a most promising crop being entirely destroyed in a few minutes; much could be said on this subject, which, however would carry me outside the scope of the present discourse.

Peltier has considered waterspouts as the effect of electric attraction rather

than of wind. This opinion he mainly grounded on the fact that in the case of 88 waterspouts observed by him the air was more or less completely calm. Such a theory will not account, however, for the uprooting of trees and lifting up of houses. Still, authors of standard works on electricity appear to think that electricity plays a part in the phenomena of waterspouts, hence I have alluded to them here.

I shall now show you Professor Colladon's instrument for the illustration of waterspouts. He has kindly lent it me, and sent it from Geneva to be exhibited to you this evening. It consists of a water receiver, at the bottom of which has been scattered some dust somewhat heavier than water. The motion given to a handle turns a wheel which imparts to the water a circular movement. Presently you will see the solid particles drawn up in a column and looking exactly like a waterspout, imitating also one of those revolving pillars of sand so often seen in sandy deserts. I witnessed one of these while on the Nile; it formed on one side of the river like a column of smoke, crossed the water in front of my boat, and after remaining on the other bank for a few seconds disappeared.

The Aurora Borealis is now generally considered as due to positive electricity from the sea between the tropics being carried into the upper atmospheric regions, and thence wafted to the poles by the higher currents of air. Here it descends towards the earth, and meets the terrestrial negative electricity in a rarefied atmosphere. Luminous discharges now take place, their brightness being increased by the presence of masses of ice particles in the atmosphere. These phenomena occur in the North and South in the neighbourhood of what are called the Magnetic Poles, and from this circumstance assume the form of bands so peculiar to these Auroræ.

I shall now conclude this address by showing you an experiment illustrating the Aurora Borealis, and which was first made by de la Rive, whose standard work on Electricity has been most useful to me in the preparation of the present discourse. This glass globe is partially deprived of the air it contained, while a powerful magnet is brought to bear upon it. You will observe the bright flashes discharged through the globe, while the luminous display assumes a peculiar rotating motion.

I owe you an apology for an address necessarily scientific and hard to understand in many respects, but having to talk about lightning and thunder, I am afraid I could not avoid entering into the history of these phenomena. The great laws of Nature are highly interesting, and every attempt to clear them up is a step in the right direction.

THE NON-EXISTENCE OF THUNDERBOLTS.

By G. J. SYMONS, F.R.S., Secretary.

[Read March 21st, 1888.]

The survival, down to the present day, of a belief in the existence of thunderbolts is a striking proof of the superficiality of modern teaching, and of the slight extent to which even the most elementary notions of electricity or physics have penetrated the mass of our countrymen.

I hope that there is not one of our Fellows that has not long abandoned such a belief; but, in case there should be one, I have obtained the permission of our Council to try to convert even him.

Of course the belief in the fall of material substances during thunderstorms is merely the survival of that in the mythical bolts which irate Jupiter hurled at his enemies;—but that the notion should still prevail with a population which may be said to be living in an age of electricity, and to be surrounded by telegraph, telephone, light, and bell wires, above our heads, below our feet, and running all through our houses, is passing strange.

Our President has illustrated to you that a flash of lightning is nothing but a large electric spark, an equalisation of potential between two unequally or differently electrified bodies; and there is no more transmission of a thunderbolt or any material substance than is there actual transmission of material substance when we send a message across (or rather under) the Atlantic.

I have been looking out for a real thunderbolt for over thirty years;—and am going to tell you very briefly the true history of several (so-called).

Notting Hill.—On July 2nd, 1866, one of the London daily papers startled some of its readers by inserting a letter on the thunderstorm of June 30th, in which the writer said, "At six o'clock the storm broke out again with increased violence, the rain descending in torrents, and at a few minutes past seven a thunderbolt fell in the gutter opposite my house (in Westbourne Park, Notting Hill), and was smashed to pieces, one of which I have at the hour at which I write. Numbers of persons are still searching for the fragments."

Feeling certain that there was a weak point somewhere, inasmuch as "thunderbolts" have no existence, I called on the writer of the letter and other residents, found the story amply confirmed, received several pieces of the "thunderbolt," which were fragments of coal, a supply having been unloaded to the next house the day previous (by the bye, some were sold at

10s. and 15s. each); and eventually I ascertained that one of the pupils of an analytical chemist had availed himself of his tutor's absence to fill a capsule with materials calculated to burn vigorously, and explode in heavy rain, and, during the height of the storm, had thrown the burning mass into the gutter, so making an artificial thunderbolt. It is no wonder that the neighbourhood were taken in by a trick so well-arranged.—*Meteorological Magazine*, Vol. I. p. 66. (Catalogue, No. 78, p. 239.)

Kilburn, July 5th, 1877.—This is a very circumstantial story, and I am glad to be able to exhibit two pieces of the thunderbolt (?) and a photograph of a third. I append the account as given in the local paper,[1] but will summarise the leading features of what I believe to have been the real facts. A small street turning out of the Edgware Road, chiefly occupied by stables, contained also the premises of a local Fire Brigade. A telegraph-wire crossed this street; an exceptionally strong flash of lightning struck, broke, and perhaps fused the wire; part of the wire fell on a little girl's hair and burnt it; other fragments fell in the street, where there was a blaze of light from the flash. Subsequently it was found that the street was strewn with clinkers—so-called even by the newspaper—and these were described

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[1] FALL OF A THUNDERBOLT IN KILBURN.—The storm which burst over the metropolis about 8 o'clock on Thursday [5th July] is described as being very severe in places, but it would certainly appear that Kilburn had the severest part of its virulence [sic], as a ball of fire of immense size fell in Bridge Street, spreading consternation in every direction, but, happily, as far as the destruction of property is concerned, little or no damage is done in the street. The telegraph wire, running from Mr. Carpenter's shop to Kilburn Park Road, was, however, completely fused, small fragments only being left, whilst the upper window of Mr. Brown's premises in Oxford Road was shattered. The scene is described as follows by several persons in the vicinity:—

Shortly after 8 o'clock a most vivid flash of lightning was observed, followed by a crash of thunder. This was succeeded by another, and then the most terrific crash, like the discharge of one of Krupp's guns, or the Woolwich Infant, and with it fell the ball of fire, or thunderbolt, to which we have alluded. This appeared to pass over with lightning rapidity from the direction of the Queen's Arms, and fell in huge masses into Bridge Street, from the door of the fire station up to the top of the street. The whole district for some seconds appeared to be enveloped in flame; the women screamed and in some cases fainted. The molten liquid, which poured down from the infuriated heavens, on reaching the ground at once coagulated, forming a clinker so heavy that in many cases they weighed over a pound and a half. Meanwhile the place was enveloped in a thick bluish yellow smoke, very objectionable, which did not clear away for some ten minutes. Persons residing in the Kilburn Park Road made sure, from the spreading of the fire, that houses in Bridge Street had been struck, and were in flames. A little girl named Frost, living at 6 Bridge Street, was struck on the head by some of the molten liquid and had her hair seriously burnt, but no dangerous symptoms are apprehended. After the flash of lightning alluded to, Bridge Street was literally strewn with a mass of clinkers; and it is estimated that were they all collected together there would be nearly two bushels of them, in size from a walnut up to a man's hand, and weighing very heavy. Simultaneously with the falling of the bolt in Bridge Street, as we have already noticed, the wire which crosses from the Post Office in Manor Terrace to the Kilburn Park Road was completely fused, small particles falling in every direction. . . . . Pieces of the clinker can be seen at the *Kilburn Times* Office.—*Kilburn Times*, July 7th, 1877.

as thunderbolts. I think that most probably they had been raked out of the steam fire-engine, but at any rate there are two difficulties which require explanation :—(1). How clinkers are formed in the sky? (2). Why they all fell in the street, and not one pierced a roof or broke a skylight? (Catalogue, No. 74, p. 239.)

Chelsea.—On June 26th, 1880, at 8 p.m., there was a sharp thunderstorm in the west of London, and it was reported that a thunderbolt had struck No. 180 Oakley Street, Chelsea, and had been found in the kitchen grate. It was further stated that it had been broken up with the poker, but that a specimen could be seen at the office of the *West Middlesex Advertiser*. This sounded rather tempting, so I went. The lump which was shown to me was an agglomeration of brick, soot, unburnt coal and cinder. I suppose that no one would suggest that bricks are manufactured in the atmosphere, or that unburnt coal is another probable component. The case was unusual because ordinarily, on a lightning discharge descending a chimney beneath which a fire is burning, it scatters the burning coals over the floor. In this instance it seems, as usual, to have swept the chimney, taking down also some fragments of brick, and then finally to have fused the contents of the grate into a cake, thus producing this so-called thunderbolt. I am sorry that all the specimens have been lost.

Surrey.—I have not the date nor precise site of this fall; but on the other hand, thanks to one of our Fellows, I have the thunderbolt (?) The story is very short. There was a thunderstorm, the lightning was seen to strike a manure heap—a hole was found in it, and on opening the heap this ball was found. Unluckily for the theory of the existence of thunderbolts this on examination and analysis proves to be a cannon ball (probably made at the old Sussex Iron works!) by which the direction of the flash had perhaps been partly directed. (Catalogue, No. 70, p. 239.)

Casterton.—Another illustrative case has come to my knowledge in connection with the present Exhibition. A large nodular concretion of red sandstone has been sent, which had been found in circumstances which very naturally led to its having been regarded as falling from the sky—but it is simply a natural formation of the soil where it was found. The narrative runs somewhat thus: A gentleman, his wife, and three daughters were looking out on a lawn at Casterton, in Westmoreland, during a thunderstorm, when they considered that they saw the stone fall in front of a tree, kill a sheep, and bury itself in the ground. After the storm the dead sheep was found, and a hole, and at the bottom of the hole this stone, which was forthwith described as a thunderbolt.

A very slight modification of the account will remove the romance, and show that the phenomena were of the most ordinary description. I venture to suggest that the spectators saw the lightning strike the tree, the lightning killed the sheep, and then, as is not infrequent, in rushing into (or out of) the soil, formed a hole. A nodule like this would be difficult of expulsion, and therefore the stone remained at the bottom of the hole. (Catalogue, No. 79, p. 240.)

Hingston Down, Callington, Cornwall.—Mr. W. B. Tripp, F.R.Met.Soc., has kindly told me of this case, which closely resembles that of the Surrey cannon ball. A farmer during a thunderstorm suddenly saw the ground ploughed up in front of him by a vivid flash of lightning, and on digging at the spot he there found the supposed thunderbolt—which Mr. Tripp, sen., at once recognised as a very good specimen of *a bronze celt.*

Brixton.—At present I possess little information respecting this fall, which took place on August 17th, 1887. A small lump (2 inches in diameter), sometimes described as a meteorite and sometimes as a thunderbolt, is stated to have fallen, but at present I cannot trace it.

Reading.—Mrs. Alfred Palmer has very kindly sent me three small lumps of earthy matter which were found in circumstances thus described. There was a violent thunderstorm in the night between July 2nd and 3rd, 1888, and the next morning the gardener found on a frequented gravel path in front of the conservatory, where it could not easily have escaped observation on the previous day, the material now preserved. It cannot have fallen from any great height, as it had "made no hole in the path—hardly a scratch." Mr. R. H. Scott, F.R.S., having submitted the specimen to Mr. Thomas Davies, F.G.S., of the Mineralogical Department, Natural History Museum, has obtained the following report:—"The lump bears no evidence whatever of meteoric origin. It consists simply of hydrated oxide of iron, mixed with some ferruginous earth, and the name 'bog-iron-ore' would probably designate its origin."

There are several facts which have been twisted into imaginary support of the theory of the existence of thunderbolts.

1st. There are the, often approximately spherical, nodules of iron pyrites which are so frequently found in the Chalk. Their weight and their structure when broken harmonise so well with mythological notions, that it is not to be wondered at that many of them are still preserved as real thunderbolts. (Catalogue, No. 71, p. 289.)

2nd. Belemnites—which, by-the-bye, I see Webster's Dictionary says are called "thunderstones" and Nuttall's "thunderbolts," though it defines the word thunderbolt as "a brilliant stream of the electric fluid." They are really fossils, but are frequently preserved as thunderbolts. (Catalogue, No. 72, p. 289.)

3rd. If a heavy discharge of lightning falls on a bed of sand containing much silex, it usually penetrates it for many feet; and along its path it fuses the sand into a sort of glass, thus producing what is known as a fulgurite (of which several very fine ones are in the British Museum). Portions of these fulgurites are sometimes considered to be thunderbolts. I regret that I have not been able to procure a specimen for the Exhibition, but there are in it two valuable drawings by Herr Dr. Fiedler, reproducing two—one of them nearly nine feet long—of their natural size. (Catalogue, Nos. 186 and 187, p. 243.) And there is also a beautiful engraving of part of one in Ribbentrop's paper on Fulgurites.[1]

[1] *Ueber die Blitzröhren oder Fulguriten von* G. Ribbentrop.—Braunschweig, 1830.

4th. Sometimes aerolites or meteorites fall during thunderstorms. There is absolutely no connection between the two phenomena; but, in the very rare cases where they have happened at the same time, the meteorite has of course been instantly designated a thunderbolt. (Catalogue, Nos. 64 to 68, p. 239.)

For our credit as Englishmen, we ought to drive the word thunderbolt out of our dictionaries. Every one can help to do this, and the greatest help of all will be, whenever one hears of a thunderbolt having fallen, not to content oneself with a shrug of the shoulders and an ejaculation as to popular ignorance, but to go to the spot, patiently examine the facts, and then explain publicly precisely what has happened. Statements as to the existence of thunderbolts require only to be brought to the light of modern knowledge to be at once annihilated.

JORDAN'S NEW PATTERN PHOTOGRAPHIC SUNSHINE RECORDER.

By JAMES B. JORDAN.

(Communicated by F. Gaster, F.R.Met.Soc.)

[Received March 14th—Read April 18th, 1888.]

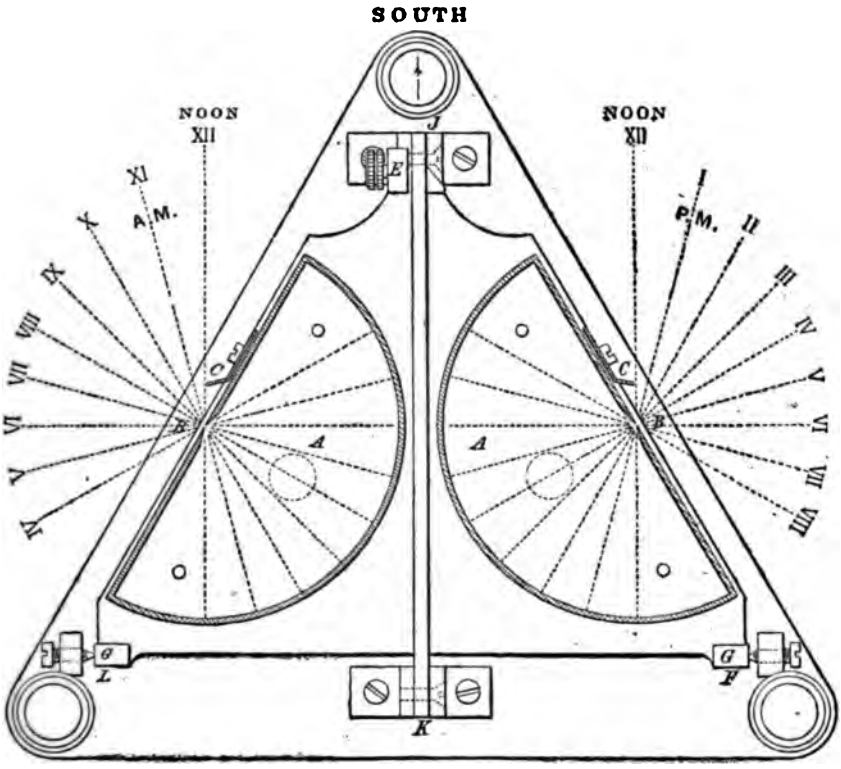
In the autumn of 1885 I had, in conjunction with Mr. Gaster, the honour of bringing before the Royal Meteorological Society a description of my Photographic Sunshine Recorder.[1] Since that date the instrument has been in the hands of many observers both in this country and abroad, and its indications have been accepted as truthful records of the duration of sunshine. The efficiency of the instrument was further proved by a trial at Kew Observatory in April last, when it was compared with the Stokes' Recorder, and after a month's observations the two instruments were found to give practically identical results, the difference between the records being less than 1 per cent. The success of the photographic method of registering duration of sunshine being so far proved, further consideration was given to the construction of the instrument, with a view to securing the recorded trace in a single straight line, at right angles to the hour lines engraved on the chart, instead of in two curved lines crossing them at varying angles which some observers find a difficulty in measuring with sufficient accuracy.

In the new form of instrument this objection has been overcome by using two semi-cylindrical or D-shaped boxes, one to contain the morning and the other the afternoon chart. An aperture for admitting the beam of sunlight

[1] *Quarterly Journal.* Vol. XII. p. 21.

is placed in the centre of the rectangular side of each box, so that the length of the beam within the chamber is the radius of the cylindrical surface on which it is projected; its path therefore follows a straight line on the chart at all seasons of the year, provided the instrument is accurately adjusted. The semi-cylinders are placed with their faces at an angle of 60° to each other; they are fixed on a flat triangular plate which is hinged to a suitable stand having levelling screws attached and fitted with a graduated arc, as a means of readily adjusting and fixing the cylinders to the proper vertical angle, agreeing with the latitude of the station where used.

The construction of the instrument will be more clearly understood by reference to Figs. 1 and 2, which show the cylinders A A in their true position; the dotted lines indicate the direction of the solar rays as they enter the apertures B B at the different hours of the day. E L F is the triangular plate on which the cylinders are fitted, and which is pivoted on the centres G G. J K is the divided arc.



PLAN.

Fig. 1.

In order to determine accurately the conclusion of the morning, and the commencement of the afternoon record, there are screens, C C, placed across the front side of each cylinder, so adjusted that the shadows projected from

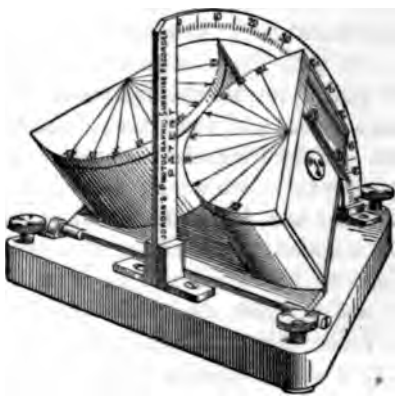


FIG. 2.

their edges shall at noon fall vertically on the apertures. At the exact moment of noon the ray of sunlight can enter both the cylinders, but immediately after noon it can only enter the afternoon cylinder, being shut off from the forenoon cylinder by its attached screen; this adjustment, however, is not essential, since the result is in no way vitiated by neglecting it, if in making up the day's record the portions of the trace overlapping the noon lines be in each case omitted.

The advantages gained by this form of my Photographic Sunshine Recorder over the preceding forms of the instrument may be enumerated as follows :—

1. The trace of sunshine is always recorded in a straight line at right angles to the hour lines which are engraved on the chart. The measurement of the trace is thereby rendered much easier and more accurate than in the earlier apparatus.

2. The apertures for the admission of the sun's rays are so placed as to receive advantageously the early and late sunshine, and as there is only one aperture in each chamber the amount of diffused light entering it is reduced by one half.

3. The fact that the morning and afternoon charts are placed in separate cylinders offers great facilities for changing the charts at convenient times of the day; for instance, the morning record can be removed and a new chart supplied any time after 12 o'clock, and the afternoon record of the previous day can be changed any time before noon, without interfering with the morning record which may be in progress at the time of changing. The two charts, if it is so desired, may be joined together, forming one continuous trace for the complete day.

4. The addition of levelling screws to the base of the instrument renders it easier of adjustment, and the readiness with which the charts can be inserted and removed from the cylinders helps to give this form of the instrument an advantage over those hitherto in use.

With respect to the working of the instrument, it need only be added that

the result of observations extending over a year proves that it is capable of registering all sunshine which is bright enough to cast a shadow.

It may be interesting to allude in conclusion to a very simple and cheap form of this class of Sunshine Recorder devised by Dr. Jules Maurer, of the Swiss Central Observatory, Zurich. Dr. Maurer has given much attention to the subject, and to him I am indebted for many valuable observations. His form of the Photographic Recorder consists of a single dark chamber, of cylindrical form, 5 inches in diameter, which is cut across obliquely at an angle of 45°, the elliptical section thus produced being covered by a thin metal plate having in its centre a rectangular aperture for the admission of the ray of sunshine, the breadth of the aperture being so determined that it shall show an interruption of sunshine of one minute duration. The lower end of the cylinder, where the chart is inserted, is closed by a moveable cover fastened in its place by a bayonet joint. The cylinder is mounted on a suitable stand fitted with levelling screws, and has an adjustment for latitude arranged somewhat similarly to that adopted in the Campbell-Stokes instruments. The merit of this arrangement consists in the fact of its producing the record in a single straight line on one chart.

DISCUSSION.

Mr. BAYARD said that Messrs. Negretti and Zambra had two or three days previously given him a copy of the certificate of comparison between the Campbell-Stokes Recorder at Kew and one of Mr. Jordan's instruments, which showed that the records from each instrument agreed within 1 per cent. He thought that the Jordan Sunshine Recorder registered more than the burning recorders, but the figures given on this certificate seemed to indicate that it registered rather less. During the month of March, he noticed that at Kew 16 per cent. of the possible duration of sunshine was recorded, while the amount recorded by a Jordan instrument at his residence at Wallington was 20 per cent.

Mr. LATHAM said that some years ago he remembered some remarks were made at one of the Society's meetings regarding the discordance observed between the register of sunshine obtained from two or more burning recorders exposed under precisely similar conditions. It appeared to him that the photographic method had many advantages. The action was more instantaneous in this class of instrument than in a burning recorder, for the burning action was slower in commencing and ceased later than the photographic action. He thought Mr. Jordan was to be congratulated on the improvement he had effected in the pattern of his instrument.

Rev. F. W. STOW inquired whether the slightest visible trace should be reckoned as sunshine, the record being at times very faint. He had commenced observations with one of Mr. Jordan's instruments recently, and had noticed on the only two days when rain fell with a strong wind, that the rain drove in at the "eyes" of the instrument, wetting the paper partially, and making a little pool at the bottom. Sometimes on snowy days the "eyes" got "bunged up."

Mr. SYMONS considered that we had not yet reached perfection in sunshine recorders. He had recently watched a burning recorder when the sun was so shining as to cast distinct shadows, and five or six minutes elapsed before any trace was burned upon the card. While the Kew certificate referred to by Mr. Bayard showed that there was good agreement between the two forms of instrument, it did not necessarily follow that both were correct. As regarded the photographic recorder, he considered that the paper used was not sufficiently sensitive. When some years since he used a Jordan sunlight recorder, he noticed that when the papers were removed from the instrument, they always

exhibited more trace of sunshine than after they were 'fixed,' as the faint traces disappeared in the process of fixing. He thought it possible that this might be avoided by using some simple chemical solution instead of ordinary water. The present form of Mr. Jordan's recorder was much better than the former patterns, and was an extremely handy instrument.

Mr. STANLEY said he considered Mr. Jordan's instrument was exceedingly clever. There was some difficulty in using blue paper for purposes of sunshine registration, as a yellowish light would have no effect upon it. He suggested that the season of the year and the time of the day should be taken into account in measuring the traces, and a suitable correction applied in order to obtain more correct records. The 'gallic' paper, which was capable of recording a very small amount of light, might perhaps be a serviceable paper for use in Mr. Jordan's recorder.

Mr. DYMOND remarked that the application of corrections, as suggested by Mr. Stanley, would lead to extremely unsatisfactory results. He had carried on observations with a Campbell-Stokes Sunshine Recorder for eight years, and his experience was that a trace could be burned on the card in three seconds.

Dr. TRIPE said that an examination of the Kew certificate, referred to by Mr. Bayard, showed that the two forms of recorders did not always register equally, for although the total for the months agreed pretty closely, the sunshine registered on individual days differed very much. The differences were very irregular, the Campbell-Stokes recorder sometimes being in excess, while at other times the Jordan instrument registered the larger amount. He thought it was likely that the differences were due to the varying amount of chemical rays in the light transmitted by the sun, and that the Jordan recorder, being photographic, was more powerfully acted upon by these rays than the Campbell-Stokes recorder, which is a heat measurer. Moisture also had a great effect upon the registration of the two instruments, and would be a source of difference between them. He had frequently noticed how greatly the power of the sun varied on days when there was no apparent difference in the atmospheric conditions, and he believed this was frequently due to the direction of the wind, as with a dry Easterly wind the sun was more burning than when the wind blew from a Westerly direction; Westerly winds being generally moist.

Mr. LECKY said he had frequently experimented with the Stokes recorder by placing a wet card in the frame, and had found that it would instantly burn. Perhaps in the instance mentioned by Mr. Symons the sun was shining through light cloud. The essential difference between Stokes' recorder and Jordan's recorder was that the latter registered sunlight while the former registered sunheat. He admired Mr. Jordan's instrument very much, especially for its simplicity.

Mr. GASTER (replying on behalf of Mr. Jordan) said that when Mr. Jordan turned his attention to the question of the registration of sunshine he noticed that the burning recorder had several defects. First, it frequently happened that there was a considerable amount of sunshine and yet the burning recorder gave no trace. Second, that when the recorder did register, the 'burr' round the spot of burning made it difficult to measure accurately the amount registered. Third, the focusing of the burning recorder was a very delicate matter, and the instruments occasionally arrived at their destination, after a long railway journey, unfit for use, having been shaken out of focus in transmission. He remembered Mr. B. Woodd Smith once stating how he had compared the registrations of three burning recorders placed side by side, and had found the amounts most discordant. Then, too, the burning recorder was a very expensive instrument. He believed, so far as London was concerned, that in winter the Jordan instrument registered more sunshine than a well-focused burning recorder. As regarded the papers used, there certainly was a difficulty to get opticians to supply good papers. The papers now supplied with Mr. Jordan's instrument were better than those first in use, and greatly prevented the disappearance of the faint traces in the process of fixing, but this latter difficulty was easily surmounted if the chart was carefully measured before placing it in water for the purpose of fixing. The new instrument was a vast improvement on the former patterns, as the trace being recorded in a straight line at right angles to the hour lines, instead of in two curved lines as previously, made the process of measuring much simpler and more accurate. He had tried a burning recorder

and one of Jordan's recorders side by side, and had found that in faint and winter sunshine the Jordan recorder registered the larger amount. The glass sphere of the burning recorder frequently became so thickly covered with hoar frost as to prevent the sun acting upon it, and on one occasion he saw a recorder in the City of London rendered practically useless by reason of the ball being enveloped in a thick accummulation of hoar frost, dew, and soot.

Mr. ARCHIBALD inquired whether lofty and nearly invisible cirrus affected the indications of the burning recorder. He had noticed that on some days there is sunshine but no sun heat.

Mr. DYMOND said that when the sunlight was strong enough to throw a shadow, the Stokes recorder always gave a trace.

Mr. LECKY observed that the Stokes recorder registered 'useful' sunshine. Mr. Lecky exhibited specimens of the cards showing distinct gradations of the sun's heat.

ON THE METEOROLOGY OF SOUTH-EASTERN CHINA IN 1886.

By WILLIAM DOBERCK, PH.D., F.R.MET.SOC., Government Astronomer, Hongkong Observatory.

[Received February 20th.—Read April 18th, 1888.]

THE accompanying tables give the monthly means and extremes of the principal meteorological elements registered in 1886 at certain of the Treaty Ports in China, which have been furnished with instruments of approved construction verified at the Hongkong Observatory. Observations made in Manila and Haiphong and transmitted through the telegraph have been utilised for comparison.

The observations were made at the Custom Houses and Lighthouses by officers of the Imperial Chinese Maritime Customs. Those made in previous years were not very reliable and the readings were often carelessly taken, as the barometers were either mercurial of very inferior construction, or aneroids of various kinds (set now and then after comparison with some more or less faulty ship-barometer), and the thermometers placed either inside the house or outside in different positions, *e.g.* just under the ceiling of a verandah exposed to the sunshine. The rain-gauges were at some stations placed under trees or bushes. The observations now made are greatly improved, as appears from the tables, but cannot be classed with those made under the directions of the Royal Meteorological Society, as the stations are not regularly inspected. There are not even funds available for the reduction of the records.

Table I. gives the monthly means of the barometer readings expressed in inches of mercury, reduced to the freezing point of water and to sea-level, except in case of Ichang, Hankow, and Kiukiang, situated on the Yang-tze-Kiang, the altitudes of which are not known. As, however, the altitude of

Kiukiang was found by myself, from a few barometer readings in the autumn of 1883, to be about 40 feet, it is easy to reduce them approximately to sea-level. The mean pressure for the year is highest along the river and lowest in the Philippine Archipelago. The annual variation is greatest inland and least in the South-east. Gradients were steepest in January (about 0·01 in. in 20 miles for North-east winds) and least in June (about 0·01 in. in 100 miles for South winds).

TABLE I.—BAROMETER.

Station.	Jan.	Feb.	March.	April.	May.	June.	July.
	In.	In.	In.	In.	In.	In.	In.
Ichang	30·19	30·25	30·01	29·89	29·78	29·67	29·53
Hankow	·28	·33	·07	29·94	·78	·69	·59
Kiukiang	·36	·39	·16	30·00	·92	·79	·73
Middle Dog	·22	·28	·12	·01	·93	·79	·79
Foochow	·27	·33	·14	30·04	·95	·81	·79
Tamsui	·19	·22	·09	29·99	·92	·83	·84
Amoy	·25	·30	·14	30·02	·94	·81	·77
Swatow	·21	·24	·11	30·00	·94	·81	·80
Fisher Island	·12	·16	·07	29·96	·93	·81	·82
South Cape	·09	·14	·05	·97	·92	·81	·82
Breaker Point	·17	·19	·07	·96	·93	·79	·78
Hongkong	·16	·19	·07	·96	·91	·79	·78
Kiungchow	·27	·26	·05	·94	·92	·80	·79
Pakhoi	·26	·27	·12	·99	·92	·80	·78
Haiphong	30·23	·27	30·11	·97	·93	·82	·79
Manila	29·98	30·01	29·99	29·90	29·87	29·86	29·86

Station.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	In.	In.	In.	In.	In.	In.
Ichang	29·62	29·87	30·01	30·22	30·23	29·94
Hankow	·62	·89	·04	·26	·33	29·98
Kiukiang	·72	·98	·11	·33	·36	30·07
Middle Dog	·71	·86	·02	·20	·25	·01
Foochow	·73	·88	30·05	·24	·30	·04
Tamsui	·75	·85	29·99	·17	·22	·00
Amoy	·71	·85	30·01	·17	·26	·02
Swatow	·76	·87	29·99	·17	·23	30·01
Fisher Island	·75	·81	·96	·08	·15	29·97
South Cape	·75	·78	·95	·06	·12	·95
Breaker Point	·73	·82	·98	·13	·19	·98
Hongkong	·76	·85	·99	·14	·20	29·98
Kiungchow	·78	·90	29·99	·16	·23	30·01
Pakhoi	·77	·89	30·00	·16	·22	·01
Haiphong	·83	·87	29·98	30·15	30·20	30·01
Manila	29·85	29·85	29·89	29·91	29·94	29·91

Table II. exhibits the mean of the maximum and minimum temperatures, as obtained from thermometers exposed in wooden screens painted white. In *Observations and Researches made at the Hongkong Observatory in 1886* Appendix A, a comparison of temperatures obtained in a Stevenson screen with the true air temperature is published, and by the aid of this the figures in this table might be corrected. As, however, the correction would be much greater in the Custom-houses, which are surrounded by buildings, than at the lighthouses, this correction has not been applied.

The highest mean temperature occurred in July. There is in summer very little change of temperature with the latitude. The temperature depends

upon the distance from the nearest sea-coast, and is greatest at stations farthest inland, at which however the correction referred to is also greatest. The lowest mean temperature occurred in January. In winter the temperature is much lower the higher the latitude, and in consequence the annual variation is great in the North.

TABLE II.—MEAN TEMPERATURE.

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
	°	°	°	°	°	°	°	°	°	°	°	°	°
Ichang	43·6	41·4	53·8	63·6	69·7	75·4	85·9	84·6	76·4	66·9	56·3	48·7	63·9
Hankow	41·6	38·1	50·9	62·1	70·3	76·7	87·9	85·2	77·1	66·9	55·1	47·7	63·3
Kiukiang	41·7	36·5	51·0	62·5	71·4	75·9	87·4	84·5	76·3	68·5	56·3	46·8	63·2
Middle Dog	50·9	43·6	50·4	58·7	67·6	73·2	79·8	79·7	76·2	72·2	63·1	54·2	64·1
Foochow	50·9	45·0	57·2	64·0	73·5	76·9	83·8	83·0	78·6	74·5	64·4	54·2	67·2
Tamsui	58·1	54·9	63·4	70·7	77·7	79·5	84·6	83·3	78·1	76·1	67·6	61·4	71·3
Keelung	[1]58·1	58·7	65·8	70·1	77·3	79·9	85·5	84·9	78·9	76·0	69·1	62·3	72·2
Amoy	56·3	49·8	58·9	65·7	74·1	78·0	82·2	83·2	81·7	78·3	69·3	59·3	69·7
Lamocks	56·3	50·8	58·2	66·3	73·5	77·7	79·7	79·4	79·0	76·7	68·1	59·0	68·7
Swatow	56·7	50·8	60·8	68·2	75·8	79·5	81·9	83·6	80·7	76·8	67·9	56·6	69·9
Fisher Island ..	61·1	55·3	63·9	70·9	74·2	76·9	79·3	79·0	78·0	75·8	69·3	62·3	70·5
South Cape	66·8	66·4	72·8	75·9	77·7	79·7	80·2	80·7	79·3	78·5	73·1	66·4	74·8
Breaker Point ..	56·4	51·3	59·7	67·6	74·4	78·7	79·8	79·8	79·4	77·6	67·2	57·5	69·1
Hongkong	58·7	53·6	62·0	69·4	75·7	79·8	80·6	81·2	79·7	76·8	69·0	59·8	70·5
Canton	58·6	51·4	65·6	71·8	78·5	80·6	81·7	83·5	81·5	78·3	70·2	65·0	72·2
Kinngchow	67·1	60·9	72·9	79·7	81·6	83·9	83·6	82·8	81·0	79·2	73·1	65·5	75·9
Pakhoi	56·9	48·3	65·4	72·6	82·3	86·7	83·4	81·5	80·6	78·0	69·2	62·1	72·2

[1] Interpolated.

Tables III. and IV. exhibit the direction and mean force of the wind. Both elements, but more especially the latter, depend upon the distance from the sea. Along the Yang-tze-Kiang the wind has a tendency to blow in the same direction as the valley runs. The North-east monsoon blows from September till June, when it dies out. The South monsoon blows in July and August, but does not blow with more than half the force of the North-east monsoon in winter. The northern entrance of the Formosa Straits is the windiest place in the "Far East" and notorious for its rough sea. The North-east wind was strongest in November, when on an average it blew a fresh breeze. The tables exhibit the mean of estimations made at noon and midnight, so that the diurnal variation is eliminated.

Table V. gives the total rainfall in inches. It is greatest in northern Formosa and least in northern China. Along the East coasts of Formosa and Luzon the winter is the wet season, especially where the mountains are high so that the strong North-east wind is forced to ascend quickly. In China July seems to be the wettest month of the year.

TABLE III.—Wind Direction.

Station.	Jan.	Feb.	March.	April.	May.	June.
	°	°	°	°	°	°
chang	E 32 S	E 15 S	E 12 S	E 42 S	S 1 W	S 77 W
Hankow	N 73 E	N 83 E	N 55 E	N 80 E	N 80 E	E 6 S
Kiukiang	N 27 E	N 35 E	N 44 E	N 38 E	N 38 E	N 42 E
Wuhu	N 37 E	N 65 E	N 74 E	N 75 E	N 58 E	E 31 S
Middle Dog	N 42 E	N 41 E	N 35 E	N 44 E	N 54 E	E 42 S
Foochow	N 41 E	N 51 E	N 59 E	N 63 E	N 59 E	N 81 E
Tamsui	N 34 E	N 32 E	N 25 E	N 40 E	E 74 S	S 12 W
Keelung.....	N 22 E	N 15 E	N 20 E	N 17 E	N 51 E	W 89 N
Chapel Island	N 44 E	N 45 E	N 42 E	N 46 E	N 61 E	N 73 E
Lamocks	N 50 E	N 45 E	N 45 E	N 47 E	N 53 E	N 69 E
Fisher Island	N 26 E	N 22 E	N 21 E	N 30 E	N 14 E	E 24 S
South Cape	N 41 E	N 48 E	N 45 E	N 61 E	N 39 E	N 25 E
Breaker Point	N 46 E	N 43 E	N 45 E	N 45 E	N 60 E	E 17 S
Hongkong	N 66 E	N 74 E	N 85 E	N 89 E	E 5 S	E 44 S
Canton	N 53 E	N 42 E	E 9 S	E 37 S	E 45 S	E 40 S
Kiungchow	N 51 E	N 54 E	N 89 E	E 18 S	E 41 S	E 45 S
Pakhoi	N 8 E	N 26 E	N 54 E	N 46 E	E 89 S	S 36 W
Bolinao	N 20 E	N 22 E	S 23 W	S 22 W	S 5 W	S 12 W

Station.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	°	°	°	°	°	°
Ichang	S 38 W	S 65 W	N 70 E	S	E 59 S	E 53 S
Hankow	E 72 S	N 66 E	N 58 E	N 51 E	N 43 E	N 81 E
Kiukiang	E 64 S	N 21 E	N 42 E	N 42 E	N 35 E	N 14 E
Wuhu	S 13 W	N 67 E	N 32 E	N 48 E	N 21 E	W 15 N
Middle Dog	E 39 S	E 37 S	N 43 E	N 42 E	N 45 E	N 38 E
Foochow	S 50 W	W 86 N	N 29 E	N 42 E	N 40 E	N 4 E
Tamsui	E 87 S	S 3 W	N 22 E	N 49 E	N 37 E	N 43 E
Keelung	E 46 S	E 48 S	N 27 E	N 47 E	N 51 E	N 54 E
Chapel Island	E 70 S	E 72 S	N 49 E	N 43 E	N 42 E	N 33 E
Lamocks	E 86 S	S 35 W	N 56 E	N 54 E	N 48 E	N 46 E
Fisher Island	E 86 S	S 15 W	N 24 E	N 22 E	N 21 E	N 22 E
South Cape	N 26 E	S 88 W	N 39 E	N 45 E	N 44 E	N 42 E
Breaker Point	E 65 S	S 16 W	N 49 E	N 46 E	N 41 E	N 39 E
Hongkong	E 41 S	S 10 W	N 71 E	N 79 E	N 67 E	N 54 E
Canton	E 49 S	E 58 S	N 51 E	N 87 E	N 48 E	N 53 E
Kiungchow	E 53 S	E 64 S	N 72 E	N 68 E	N 30 E	N 50 E
Pakhoi	S 8 W	E 78 S	N 3 E	N 66 E	N 12 E	N 64 E
Bolinao	S 8 W	S 36 W	S 10 W	S 47 W	N 36 E	N 59 E

TABLE IV.—Wind Force. (Beaufort Scale.)

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Ichang	1·2	0·7	1·4	0·8	0·6	0·7	1·0	0·6	1·3	0·7	1·7	1·6	1·0
Hankow.....	1·8	1·4	1·5	1·4	1·7	1·5	1·6	1·9	1·2	1·8	1·5	1·3	1·6
Kiukiang	2·5	2·3	1·6	2·1	2·0	2·0	1·5	2·4	3·6	2·3	2·2	1·4	2·2
Wuhu.....	2·6	2·7	2·5	2·2	2·1	2·1	1·7	2·1	2·1	2·1	1·8	2·2	2·2
Middle Dog ...	4·6	5·2	4·0	4·1	4·1	4·4	2·6	3·7	4·5	4·5	5·8	4·9	4·4
Foochow	1·9	1·7	2·3	1·9	1·7	1·5	1·8	2·0	2·6	2·2	2·7	1·6	2·0
Tamsui	4·2	4·2	3·2	2·9	2·4	2·4	2·3	2·7	3·4	2·6	3·6	2·9	3·1
Keelung.....	3·9	4·5	2·7	2·3	2·4	1·9	2·5	2·1	1·8	1·4	2·1	1·5	2·4
Chapel Island ..	3·9	4·2	2·4	2·7	2·5	2·6	2·0	2·5	3·6	3·6	4·9	4·4	3·3
Lamocks	4·5	5·1	3·6	3·6	2·6	2·7	2·1	1·8	3·2	4·1	5·7	4·9	3·7
Fisher Island ..	4·0	4·6	2·6	2·8	2·2	2·4	1·6	2·2	3·8	3·9	5·6	4·9	3·4
South Cape	4·0	3·9	3·5	2·8	2·7	2·4	1·8	2·6	2·5	3·7	4·7	4·1	3·2
Breaker Point ..	4·4	4·6	3·6	3·5	3·6	3·0	2·6	2·6	3·5	3·9	4·9	3·9	3·7
Hongkong	2·1	2·7	2·6	2·7	2·3	1·7	1·7	1·3	1·2	2·4	2·5	2·2	2·1
Canton	2·0	2·0	1·7	1·5	1·6	1·1	1·2	1·3	1·1	1·3	1·3	1·5	1·5
Kiungchow	2·6	3·0	2·7	2·5	1·7	1·9	1·7	1·8	1·8	2·9	3·5	2·9	2·4
Pakhoi	2·7	2·9	2·1	1·9	2·0	1·9	2·3	2·3	2·4	2·6	2·6	2·3	2·3
Bolinao	2·4	2·4	2·1	2·1	1·8	1·8	1·7	1·8	1·7	1·9	2·4	2·1	2·0

TABLE V.—Rainfall.

Station.	Jan.	Feb.	March.	April.	May.	June.	July.
	In.	In.	In.	In.	In.	In.	In.
Ichang	·33	·35	1·59	4·50	5·95	6·85	10·40
Hankow	·44	1·60	4·00	8·75	10·23	10·40	1·53
Kiukiang	2·18	4·10	6·26	7·02	7·53	15·34	·49
Wuhu	·82	1·81	4·85	4·64	6·38	12·90	1·92
Middle Dog	3·22	3·30	3·88	6·75	4·27	9·31	·73
Foochow	1·97	2·82	3·46	5·98	4·12	11·02	7·70
Tamsui	7·17	5·83	4·65	8·78	·82	11·88	2·19
Keelung	11·06	19·01	12·61	11·22	2·75	11·71	·95
Amoy.....	5·00	2·52	2·26	7·40	·20	2·65	9·43
Lamocks	2·08	·68	2·88	8·35	1·92	2·30	11·43
Swatow	4·81	·95	3·88	7·48	·21	2·89	13·75
Fisher Island ..	1·26	·72	3·02	4·81	·64	6·78	2·14
South Cape	3·05	2·22	2·73	4·86	1·10	14·93	18·69
Breaker Point ..	2·87	·99	3·71	3·58	·82	4·30	16·71
Hongkong.....	2·01	1·54	2·59	5·68	3·56	8·87	28·32
Canton	2·50	2·37	3·13	9·88	..	13·25	11·12
Kiungchow	..	..	7·88	3·40	5·70	5·00	8·80
Pakhoi	·30	3·89	6·90	2·40	3·19	3·45	19·34
Manila	..	·65	..	1·43	2·86	7·65	10·95

Station.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	In.	In.	In.	In.	In.	In.
Ichang	6·18	2·22	6·42	·26	·09	45·14
Hankow	1·47	1·15	11·08	·55	..	51·20
Kiukiang	5·34	·74	9·24	·21	·06	58·51
Wuhu.....	5·69	2·24	5·57	·10	..	46·92
Middle Dog	6·24	3·56	·57	·09	1·74	43·66
Foochow	8·68	2·87	·26	·07	1·43	50·38
Tamsui	5·93	13·93	1·90	4·76	5·73	73·57
Keelung	8·88	31·43	6·01	10·57	7·73	133·93
Amoy	4·60	1·52	·09	..	1·50	37·17
Lamocks	6·11	·63	..	..	2·51	38·89
Swatow	7·98	2·27	..	..	2·50	46·72
Fisher Island	2·93	2·18	·04	..	1·96	26·48
South Cape	20·92	22·80	·83	·42	2·94	95·49
Breaker Point	6·21	3·92	·07	..	1·49	44·67
Hongkong	8·96	2·99	2·82	·05	1·77	69·16
Canton	6·75	4·50	..	..	·70	54·20
Kiungchow	5·40	1·70	5·50	2·30	·50	46·18
Pakhoi	15·98	2·74	1·23	..	..	59·42
Manila	5·96	8·04	15·21	3·24	4·11	60·10

The approximate geographical latitudes and longitudes of the stations are as follows :—

	°	′		°	′	
Ichang	30	12	N	111	19	E
Hankow.....	30	33	,,	114	20	,,
Kiukiang	29	43	,,	116	7	,,
Wuhu	31	22	,,	118	22	,,
Middle Dog	25	58	,,	120	2	,,
Foochow.....	26	8	,,	119	38	,,
Tamsui	25	10	,,	121	25	,,
Keelung	25	8	,,	121	45	,,
Amoy	24	27	,,	118	4	,,
Lamocks	23	15	,,	117	18	,,
Chapel Island	24	10	,,	118	13	,,
Swatow	23	20	N	116	43	E
Fisher Island	23	33	,,	119	28	,,
South Cape	21	55	,,	120	51	,,
Breaker Point	22	56	,,	116	28	,,
Hongkong	22	18	,,	114	10	,,
Canton	23	7	,,	113	17	,,
Kiungchow.....	20	3	,,	110	20	,,
Pakhoi	21	29	,,	109	6	,,
Haiphong	20	52	,,	106	40	,,
Bolinao	16	24	,,	119	55	,,
Manila	14	36	,,	120	58	,,

The reductions and calculations have been made under my superintendence by Mr. Mahomet Alarakia, Second Assistant in the Hongkong Observatory.

DISCUSSION.

Captain MACLEAR said that the weather at Hongkong did not fairly represent the weather on the south-east coast of China, as the place was rather sheltered, although typhoons strike it. The typhoons had their origin to the eastward of the Philippines, and the earliest information concerning their formation was obtained from Manila. The Director of the Manila Observatory had informed him that his staff was always able to foretell the approach of a typhoon, and the direction in which it would move, but could not forecast its force nor extent.

Mr. ABERCROMBY said that the most interesting part of this paper was that it brought out what was now a well-known fact, viz. that in the monsoon districts the rainy season is on the windward side of islands. For instance, in Formosa and Luzon, as in Ceylon, the rainy season is on the east coasts during the North-east monsoon, but on the west coasts during the South-west monsoon.

Mr. BLANFORD said that these observations gave an idea of a year's climate in this district, and the data were valuable as having been recorded with verified instruments. This was not the case with the three or four years' observations at the same stations which had been discussed by Dr. Thirring in the August number of the *Meteorologische Zeitschrift* for last year. These latter, however, contained the only information hitherto published relating to the interior of China.

LIGHTNING IN SNOWSTORMS.

By Prof. A. S. HERSCHEL, D.C.L., F.R.S.

(Communicated by Capt. J. P. MACLEAR, F.R.Met.Soc.)

[Received March 21st—Read April 18th, 1888.]

On the evening of Monday, February 13th, 1888, I returned to Hawkhurst in Kent, from near Dorking, having enjoyed a sunny day's drive about the Surrey hills in the neighbourhood of Gomshall. The blue sky had been dotted with white cumuli, and, although cold the day before, the temperature in the sunshine had now become quite mild, and the air had all day been quite calm. Alighting from the train for a four miles' walk at half-past five, an approaching change was beginning to be visible in the sky; clouds were gathering, and the sun having set, they darkened the twilight very rapidly at about six o'clock, without drifting over apparently from any quarter in particular. A few minutes after half-past six, when I had reached Hawkhurst parish, with scarcely light enough left for picking out a footpath, the darkness was suddenly lit up by a bright flash, as of lightning. The occurrence of an electrical flash, however, in cold weather, without either wind or rain, seemed so anomalous, that supposing that a meteoric fireball had burst behind the clouds, among gaps in which several of the brighter stars were visible, I kept a watch upon these gaps to detect, if possible, any luminous streak which the meteor might have left in passing, counting seconds meanwhile to note the lapse of time until a report might be heard, if the meteor produced any audible detonation, or if thunder should follow the flash, if it was electrical. No sound ensued for three and a half minutes, during which I walked across an open grass-field, and there was no repetition of either a near, or of a distant, flash of light while this time was regularly counted.[1] Then while crossing a stile from the field, which the darkness made very difficult to find, I heard a low but very distinct roll of distant thunder coming from not far above the horizon in the direction of about North-north-east. Lighting a match and reading my watch without any difficulty from wind, as the air was still calm, I found, allowing for the time that had passed, and with correction of

[1] Forty-eight alphabets were repeated, each occupying, at my usual rate of pronouncing them, four-and-a-half seconds, or altogether 216 seconds.

the watch to railway time, that the flash of light appeared at 6.37 p.m. A few minutes more of walking brought me to shelter at Hawkhurst, when snow in hail-like pellets was just beginning to fall pretty smartly. This fall of snow grew thicker, changing to large flakes and accompanied by a rising wind. At eleven o'clock the same evening the gusts of wind were violent, and a thick covering of snow had fallen, while an aneroid which was marking rather high had indicated no change of reading since sunset.

Unless the sound heard was the report of a distant cannon, some sounds of practice of which are sometimes here audible, it is difficult to account for the thunder-like explosion otherwise than as that of a detonating fireball, as the distance of the flash, in about the direction and neighbourhood of Woolwich, if it produced the sound, must have been, by the time which the latter took to reach the ear, about forty-four miles, while the thunder from lightning is rarely audible to a further distance than twelve miles, or to distances which sound requires fifty or sixty seconds at the most to travel. But though no flash of any kind was seen in the perfect darkness, and with careful watching in the long interval, there yet seems a strong presumption that both the flash and the report may in some way have been electrical, from the concurrence of other evidence that the long period of snowy weather which succeeded was ushered in at about the date of this occurrence by considerable electrical disturbances at other places.

The following notice of a short sharp thunderstorm at Porthcurno Cable Telegraph Station, near Land's End, on the evening of Tuesday, February 14th last, which in a few minutes did much mischief by lightning at the station, appeared in the *Electrician* of February 24th, 1888 (Vol. XX., p. 413) :—

"Lightning discharge at a Cable Station. Efficiency of the Saunders Lightning Guard.—The Eastern Telegraph Company's Station at Porthcurno, near the Land's End, was visited on the night of the 14th inst by a thunderstorm, which, although it lasted only about five minutes, was very severe.

"The storm burst so suddenly that there was no time to put the cables to earth. In an instant the Office seemed to be brilliantly illuminated, the sparks proceeding from the cable connections being so vivid as to dazzle the eyes, and in the test-room the noise of the discharges was as loud as from a big electrical machine, or the cracking of a whip.

"The lightning appears to have struck near the front of the building without doing any damage to the structure, and passed through the test-room. The land-line connections are at the other end of the station, and nothing was noticed near their lightning protectors.

"The recorder coils on the Vigo and Lisbon cables, which had Siemens' Lightning Protectors only, were fused. It was at first thought that the coil of the Gibraltar instrument was fused also, but it is protected by a Saunders fine wire and tube protector, and to this fact its safety is attributed. The platinum wire was fused, and it did its work and saved the instrument, putting the cable to earth.

"The Eastern Telegraph Company have often had reports of the efficiency of the Saunders Lightning Guard, which is in use at almost all their Stations, but in this case the proof is so clear that in future it will in every case be used in addition to a Siemens' plate-guard."

In another direction, and later in the same week, a private communication from Nice, in the South of France, describes Monday, February 13th, as such a pouring wet day that though processions were held in splendid weather on the previous and following days of February 12th and 14th, yet the intended Carnival Fête of Flowers was postponed from that day to Thursday, February 16th, "when the weather was again perfect. But since then it has taken its revenge, and on Saturday and Sunday (February 18th and 19th) we had heavy snow and frightful thunderstorms during both nights, followed by torrents of rain which soon washed away the snow from the town, but the hills all around are still thick with it. The Niçois people who have lived here all their lives declare they never recollect such a winter. There was snow also in Florence the day before yesterday (February 22nd)."

Although the evidence thus points to much electrical disturbance having accompanied the first outbreak in February of the recent heavy snowstorms, yet it is notable that a date of maximum frequency of aerolitic and detonating meteors has been recognised from catalogues of their occurrence as falling on February 12th-14th, and an observation of a very brilliant fireball is recorded by Mr. W. F. Denning in his "Meteor notes" for last month, in this month's issue of *The Observatory*, as having been seen near Leeds on the first night of those yearly dates.—"On February 12th, 1888, Mr. T. P. Teale, writing from Leeds, says, 'On my way to Headingley Church this evening, within a few seconds of 6.30, and looking due north, I saw a large meteor. It took an almost horizontal course from east to west, about 20° above the horizon, and seemed to last three seconds, passing through an arc of about 20°. It disappeared, or at least became faintly visible, two or three times, as if passing behind thin layers of

mist. It looked much like a rocket, and did not as far as I could see leave a luminous track, nor did it end in coloured sparks.'" An open subject for enquiry is therefore perhaps still left for trial and consideration, by collecting observations on those dates in February last, if perhaps any observers residing in this part of Kent or in some other counties may have noted a similar luminous appearance on that day, whether the bright flash and detonating sound observed on the evening of Monday the 13th ult. in this locality of Kent was really a lightning flash or a detonating fireball.

POSTSCRIPT, *April 14th.*—Some further evidence of different kinds obtained since writing the above, now appears to me to negative the supposition made in explanation of the flash and sound observed on the evening of February 13th, that they may have been effects produced by a solid meteorite's collision with the atmosphere. In the first place sounds of cannon-firing have not unfrequently been heard, of late, on calm days at Hawkhurst, proceeding from a northerly direction. It may be that these have been produced by firing-practice with a 110 ton gun, which I have been informed has recently been taking place, from time to time, at Sheerness. While, however, the use of such a large gun would probably not be made after dark, when this thunderlike report was heard, observations recorded at almost the same time, at places in Sussex, close to which county's north-eastern boundary the village of Hawkhurst is situated, indicate, as has been related to me by Mr. Marriott, Assist.-Sec. of the Royal Meteorological Society, that symptoms of a thunderstorm of short duration had there also made themselves perceptible.

On the evening of February 13th it was recorded, as Mr. Marriott has informed me, both at Arundel and at Cocking near Midhurst, in the same county, that lightning and thunder were observed at a few noted times between about half-past six and a quarter to seven o'clock.

The observed interval of one minute between lightning and thunder, at Cocking, if it was exactly noted, was itself an extremely lengthy one for a thunder-peal's transmission, corresponding to a distance of audibility of the thunder-claps of only the very largest and strongest English lightning-flashes. But the interval of three and a half minutes observed about ten minutes later at Hawkhurst surpassed even that long duration very greatly, and the sound was yet preceded by no visible flash there to which it might with any probability be attributed.

The thunder-peal noted at Arundel at 6.40 is not stated to have had any visible lightning flash as its precursor; nor are the lightning and thunder noted at 6.45 said to have been directly connected with each other, but the thunder perhaps also followed, as at Hawkhurst, some previous lightning-flash of which no scattered light or other visible appearance in the sky could there be detected.

Should it be possible to base any safe argument and conclusion on such apparently fragmentary and imperfect data, I am inclined to offer as an explanation of the occurrence of distant thunder, as at Hawkhurst and perhaps also at the two above-named places, without any slightly earlier lightning flashes to account for it, by supposing that the flashes which produced the thunder were so completely concealed where they took place, in excessively dense storm-clouds, that, as daylight itself in cases of very thick condensation may be almost turned to darkness, the brightness of the flashes to which the thunder-peals were owing was unable to radiate from within the opaque snow clouds by which they were environed sufficiently to attract external attention to any visible luminosity either of the flash itself or of its reflected light among the clouds. Yet loud sounds, as for example shoutings of the voice, as has been placed on record by Professor Tyndall as one of the most noteworthy of his scientific experiences among the Alps, are transmitted with extraordinary freedom and distinctness through a snow-laden atmosphere, so that communications of words could be clearly carried on and conveyed through tracts of air so thickly filled with showers of falling snow as quite to shut out the view of one of two conversing persons from the other. Sounds of thunder might then reach the ear at great distances from the interior of the thickest snow-clouds, although the light of lightning-flashes which produce them there may be very greatly, or entirely intercepted.

The strength of the gale and the thickness of the snowfall which quickly

succeeded these brief-lasting symptoms of electrical disturbance, during the evening hours of February 13th last, may account perhaps in this way for invisible lightning-flashes of which the rolling thunder at a great distance could be heard distinctly in the direction of the approaching storm, although their light, which must have preceded it by scarcely more than a minute for each rumbling peal, could yet, at least while it was being carefully watched for at Hawkhurst, not be at all noticed or detected there.

DISCUSSION.

Capt. MACLEAR said that he and Prof. Herschel were together on February 13th and parted company noting the coming weather. They had corresponded the next day respecting the weather experienced and on comparing notes found that the snow commenced to fall at Hawkhurst and at Cranleigh, near Guildford, at the same time, but no lightning was seen at Cranleigh. He believed that the report from the firing of the 110-ton guns could be heard at Hawkhurst, but he had made inquiries and found that no trial of these guns took place on that day.

Mr. DYMOND said he had heard the report of guns fired at Spithead when on the borders of Somerset and Devon. It was also a well authenticated fact that the evening gun fired from the citadel of Plymouth had been heard at Falmouth, a distance of about 70 miles.

Mr. SYMONS said regarding the distance at which the report of gun-firing could be heard that the noise of the battle of Waterloo was heard in the Eastern counties of England, and the salutes fired at Cherbourg in honour of the visit of the Queen to the Emperor Napoleon III. were audible in Dorsetshire, the former being about 160 and the latter nearly 100 miles. The report of the Krakatoa explosion was heard at places more than 2,000 miles distant, and the noise of the eruption of the volcano of Tomboro was heard at a distance of 900 miles.

Rev. F. W. STOW said that it was hardly fair to compare the loudness of thunder with that of heavy guns, or of a volcano eruption, by noting the distances at which the sounds were respectively heard, because sounds on or within the earth could be heard very much further than those transmitted by the air.

Mr. C. HARDING remarked that sounds made on the surface of the earth could be distinctly heard in a balloon even when at a good elevation.

Mr. GASTER said that he had distinctly heard the beating of the paddles of a steamer on the surface of the sea at evening time when on a pier at a seaside resort, although the steamer was at least 10 miles distant.

FIRST REPORT

OF THE

THUNDERSTORM COMMITTEE.

ON THE PHOTOGRAPHS OF LIGHTNING FLASHES
Received by the ROYAL METEOROLOGICAL SOCIETY.

Drawn up by the Hon. RALPH ABERCROMBY, F.R.Met.Soc.

[Read June 20th, 1888.

In the month of June 1887, the Committee issued about 200 circulars to the Secretaries of Photographic Societies in various parts of Europe and America, and also to other likely persons, requesting them to furnish the Royal Meteorological Society with photographs of Lightning flashes.

About 60 photographs of Lightning flashes were received in answer to this invitation; and these were exhibited at the Meeting of the Society in March 1888, where they received much attention.

From the evidence now obtained it is evident that Lightning assumes various typical forms, under conditions which are at present unknown.

The following appear to be some of the most typical forms of Lightning flashes:—

1. *Stream Lightning*, or a plain, broad, rather smooth streak of light.—Only two or three specimens of this form have been received. The Committee are disposed to consider this a distinct type of a single stream-like character, without distinct irregularities or branches, and not merely the result of bad focussing, because, as in the illustration here given, other objects—such as the trees—are extremely sharp.

An example is given in No. 1 of Plate III. from a photograph taken by Mr. L. S. Clarke, Pittsburg, Pennsylvania, April 1886.

2. *Sinuous Lightning*, when the flash keeps in some one general direction, but the line is sinuous, bending from side to side in a very irregular manner. This is by far the commonest type.

It is very noticeable that the thickness of the line varies during the course of discharge. Sometimes the thinnest part of the white streak is the highest, and the flash appears to get thicker as it approaches the earth; at other times a flash in the air begins thin, broadens out in the middle, and fines away again at the further extremity.

The Committee can offer no explanation of this at present, but they would call attention to the fact that in some photographs of electric sparks taken

from an induction coil, those of high tension are thinner than those of low tension.

An excellent example of this sinuous type is given in No. 4 of Plate III. from a photograph taken by Mr. L. S. Clarke from the top of the Alleghany Mountains on August 2nd, 1887.

3. *Ramified Lightning*, in which part of the flash appears to branch off from the main streak like the fibres from the root of a tree. Of course there is no evidence as to whether these fibres branch off from, or run into, the main flash.

A beautiful illustration is given in No. 2 of Plate III. from a photograph by Mr. E. S. Shepherd, in London, at 9 p.m. on August 17th, 1887.

4. *Meandering Lightning.*—Sometimes the flash appears to meander about in the air without any definite course, and forms small, irregular loops. The thickness of the same flash may vary considerably in different parts of the course, as mentioned above; and a flash may go pretty straight in one portion of its path, but meander considerably in another.

An example is given in No. 8 of Plate III. from a photograph by Mr. J. Gray, at Brixton, at 9 p.m. on August 17th, 1887. This is the same storm as that which produced the ramified flash shown in No. 2, and one of the fibres of that flash is curiously meandering.

5. *Beaded or Chaplotted Lightning.*—Sometimes a series of bright beads appear in the general white streak of Lightning on the photographic plate. Occasionally these brighter spots appear to coincide with bends in a meandering type, as in No. 8, Plate III.; but often the beads appear without any evident looping of the flash.

But as a flash is moving in space, while two directions only can be shown on the plane of the paper, there is every reason to believe that the brighter spots on the positive picture may be points where the flash was zig-zagging, either directly towards, or away from, the observer, and thereby giving a somewhat longer exposure to these spots.

It may be remarked that the photograph of the spark derived from a large influence machine by Mr. Wimshurst and engraved in *Engineering* for April 27th, 1888, p. 420, shows distinct beading in places. This is reproduced, in fig. 1a (p. 231), through the courtesy of the publisher of *Engineering*.

6. *Ribbon Lightning.*—Nearly one-sixth of the photographs received by the Society show flashes exhibiting more or less of a ribbon-like form. One edge of the ribbon is usually much whiter and firmer than the other.

Occasionally in the same picture, some flashes appear normal and others ribboned; but the flashes in a picture need not have occurred simultaneously. The Committee have not yet in their possession any conclusive evidence as to whether the *same* flash may be normal in one portion, and ribboned in another portion of its course.

In one picture there is a bright streak on the top of the flash; then about $\frac{1}{8}$th inch of ribbon-like light, the folds following the sinuosities of the bright streak; then a dark band, parallel to, and following, every irregularity of the bright streak; and then nearly another $\frac{1}{8}$th inch of ribbon-like light. In

another picture a very thin beaded flash has a precisely similar beaded streak, rather fainter than itself, running parallel to it, at a distance of about $\frac{1}{15}$th inch on the paper.

It might be suggested that the second fainter image was formed by internal reflection from the back surface of the glass plate; but it should be noticed that sometimes very thin flashes, which are not particularly bright, are so duplicated.

A far more probable cause is the double image formed by the internal reflections of doublet photographic lenses. All doublets are essentially two meniscus lenses, mounted with their concave surfaces facing one another. The greater portion of a strong point of light, passing through both lenses, forms the usual image on the plate; but a smaller portion is reflected from the concave surface of the rear meniscus on to the concave surface of the front lens, and from thence back through the rear lens to the sensitive plate. The amount of displacement depends on the angle formed between the direction of the bright point and the optical axis of the lens.

Mons. C. Moussette of Paris showed the writer of this Report some photographs of the sun in which this double reflection image was very conspicuous; and there is not the slightest doubt that some Lightning flashes are bright enough to give this secondary image. Mons. Moussette also showed the writer the photograph of a flash in which the centre of the flash was whitest, with a darker edge on either side. This may have been produced either by double reflection from the lens, or by internal reflection from the back of the glass plate. Two bands of light—the primary and secondary images—slightly overlapping, would form an extra bright band where the overlap took place.

In the majority of cases, the folds of the ribbon formation are most obvious when the course of the flash is square to the width of the folds, and they are but slightly pronounced when in a line with them. This would suggest the idea of a shaking of the camera in the direction of the folds of the ribbon; but if this is so, the duration of a Lightning flash must be much longer than is usually supposed.

The Committee hope to have the opportunity of making some experiments on the photography of sparks from a coil or electrical influence machine.

The Committee in the meantime must defer expressing an opinion as to whether Lightning ever really takes a ribbon-like form till further evidence is available; but would point out that both sources of error—the duplication of the image either by reflection inside the lens, or by reflection from the back of the plate—would be avoided by the use of single lenses, and of paper instead of glass supported films. The Committee also forbear for the present from publishing a reproduction of a ribbon-like flash, till they are satisfied that such a form of lightning really exists; and that the whole appearance is not due to photographic causes.

Anomalous Appearance.—In one picture sent, by Mr. Shepherd, there are five ordinary white flashes and one dark streak of precisely the same character as the bright streaks. Mons. Moussette has suggested that this may be the result of a very bright flash, so over-exposing the plate as to produce the

well known inversion of a negative by over-exposure, as when the ball of the sun appears black on the positive print, instead of white. This is no doubt a possible explanation; but the Committee would like further examples of this same appearance of dark flashes before expressing an opinion on the matter.[1]

Pictorial Representation of Lightning.—The Committee wish to call attention to the fact that there is not the slightest evidence in the photographs of Lightning flashes of the angular zig-zag, or forked, form commonly seen in pictures.

In connection with this, they would call attention to a remarkable paper communicated to the British Association in 1856, by James Nasmyth, F.R.S. (*Report Brit. Assoc.* 1856, p. 14). Mr. Nasmyth says that he has never seen forked Lightning such as fig. 1, and asserts that "the true natural form of a primitive flash of Lightning appears to Mr. Nasmyth to be more correctly represented by an intensely crooked line, as indicated in fig. 2; and on several occasions he has observed it to assume the forked or branched form indicated in fig. 3, but, as before said, never in the zig-zag dovetail of fig. 1."

The photographic reproductions of Lightning flashes appended to this Report (Plate III.) are a striking commentary on Mr. Nasmyth's accuracy, both as an observer and as an artist.

FIG. 1.—Artists' Lightning, after Nasmyth.

[1] It is to be remembered that where the flashes cross each other, and consequently produce a double exposure of those parts of the sensitive plate, no darkening is observable.

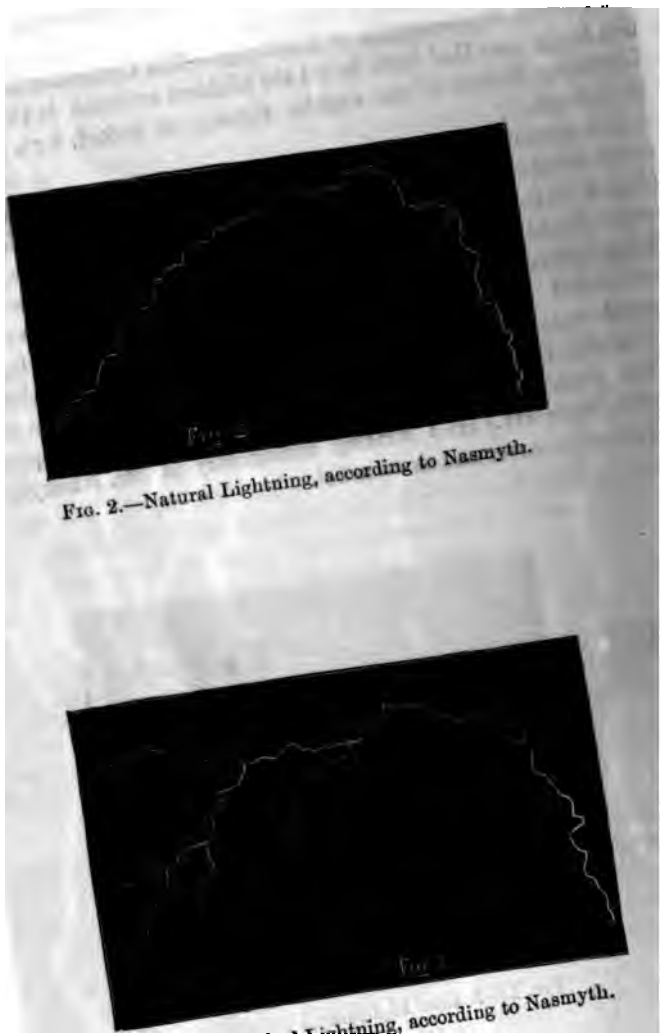


FIG. 2.—Natural Lightning, according to Nasmyth.

FIG. 3.—Branched Lightning, according to Nasmyth.

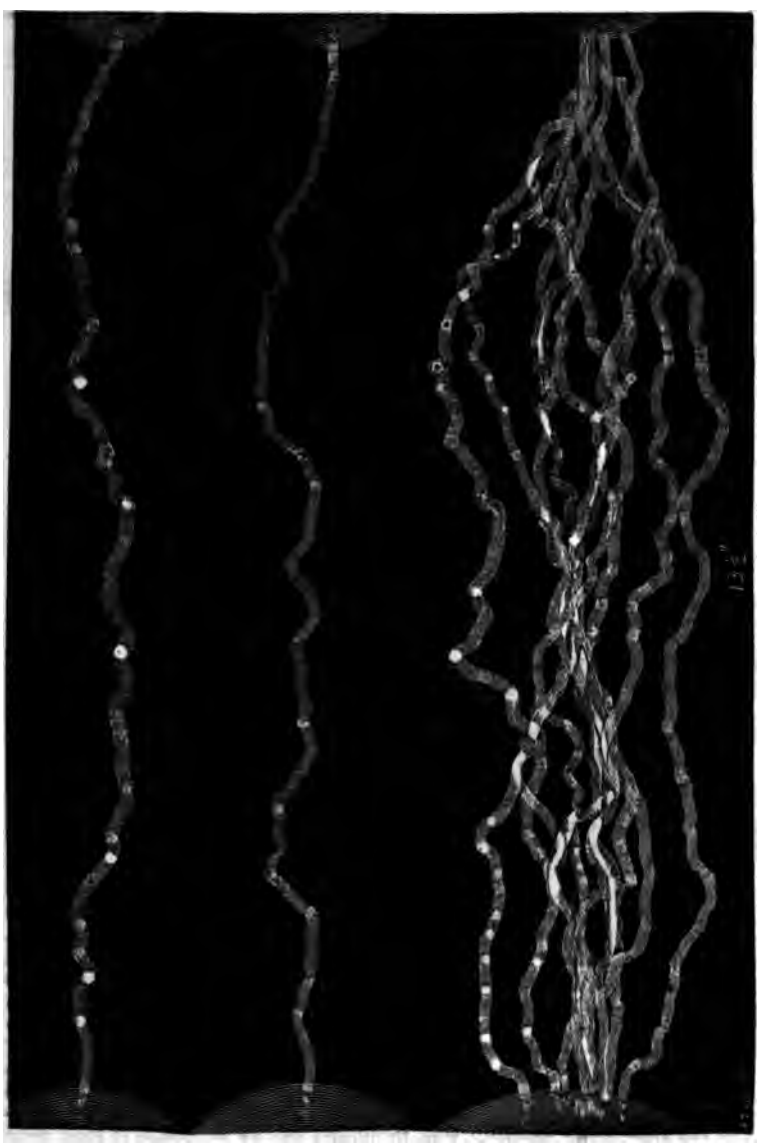


FIG. 14.—Discharge from large electrical influence machine, by Mr. Wimshurst, showing bright beads in the streaks of light.

DISCUSSION.

THE PRESIDENT (Dr. Marcet) said that the subject of lightning could not be satisfactorily discussed until exact representations of lightning flashes were available. The lightning photographs received by the Society gave evidence of the nature and formation of such discharges, and we now had, in black and white, faithful representations of various shapes and forms.

Mr. SCOTT read a letter from Prof. Stokes, who was unavoidably prevented from being present. He said, with regard to the bright spots in the diagram of sparks from Mr. Wimshurst's electrical machine, and also the spots shown in some of the lightning photographs, that he believed them to be due to foreshortening, although, in the case of Mr. Wimshurst's diagram, the exactly globular character of all the spots led him to believe that the engraver was responsible for their formation. The duplication of the flashes in a few of the photographs was probably due to one flash, quite independent of the other, following another almost instantaneously and along nearly precisely the same track. In one case, however, the tracks ultimately diverged wide apart. The dark flash noticed in one photograph was perhaps produced by a previous flash, before the cap over the lens was taken off, which had produced nitrous oxide along its track. The actual flash photographed would then illuminate the background of cloud, but this light could not pass through the nitrous oxide, and thus would give a dark track due to absorption. If the dark flash were due to over-exposure, its edges would be bright, as it is a photograph of a luminous object in a transparent atmosphere. The sun is luminous all over, but it is practically an opaque body. In the case of the curtain form of flash, with a dark line cutting across it, but not at all points, this was possibly due to the second curtain flash having been partly before and partly behind the track of the first, which produced the nitrous oxide. In all cases the dark lines were probably due to nitrous oxide.

THE PRESIDENT (Dr. Marcet) said he had many times thrown an image of an electric spark, magnified by means of a lens, on to a white screen, and had thus obtained streaks of light from 6 to 12 feet in length, but he had never seen the bright spots or beads shown in the diagram of sparks from Mr. Wimshurst's electrical machine. He must have noticed any irregularities or peculiarities in the flashes had there been any, as the electric spark was so considerably magnified.

Sir W. W. SMYTH exhibited a piece of looking-glass which had been struck by lightning, and in which the quicksilver covering at the back had been stripped off in various stream-like forms. He gave the following account of his experience on the occasion when the damage was done. He was at Crake Scar, above St. Helen, Auckland, in Durham, on September 29th, 1887, for the purpose of inspecting a colliery, and in the afternoon while waiting for the manager he noticed a thunderstorm coming on from the North-east. The place was very high and much exposed, and he could see the storm approaching from the vicinity of Sunderland. On the arrival of Mr. Shipley, the manager, and having disposed of tea in the "Edge House" inn near, he proposed to wait until the storm had passed over. There was a good fire in the room, and they sat one on each side of it, conversing on various matters connected with the colliery. One of the three paraffin lamps in a chandelier was also lighted, as it was becoming dark, though little after 5 o'clock. Meanwhile the thunderstorm gradually approached nearer, the thunder getting louder, when suddenly, without any warning, a dazzling electric light dashed into the centre of the room, seeming to come from the chimney. Instantly there was a terrific report, and a crash of falling fragments of glass, and he and his companion were completely dazed, so that they could neither see nor hear for a few moments. The lighted lamp was extinguished and its glass smashed. The whole occurrence was so instantaneous and startling that there was no time to analyse what had happened. Their first proceeding in the succeeding darkness was to inquire one of the other if they were all right. Amid screams from other parts of the house the landlady rushed in with lights, and they found that a haze filled the room, that the mirror over the mantelpiece had been dashed into fragments, the gilding taken off the frame, and everything swept off the mantel shelf into the middle of the room. The manager of the colliery had sustained one or two slight cuts on the head

from the particles of glass which had been hurled over the room, but otherwise they were uninjured. In the course of the evening he (Sir W. W. Smyth) found his head and clothes sprinkled with small metallic-looking particles, which were so fused to his hair and the cloth of his coat, that they were exceedingly difficult to remove. When examined under the microscope these particles resembled fulgurites. These were obviously from the "silvering" of the looking-glass. He had not yet ascertained of what the particles were actually composed, but he still had some adhering to his coat. Mr. Shipley carefully examined the house subsequently, and could find no indications of how the lightning entered the room in which they had encountered their extraordinary experience. In the room adjoining (a kitchen), the chimney of which branched off from that of the front room, an enormous amount of soot was deposited, and it was found that the bell wires in the sitting-room, which were of copper, had been fused. The mirror, portions of which were sent on to him by Mr. Shipley, had in places completely lost its reflecting properties, the quicksilver and other material being entirely removed. The fragment exhibited had been presented to Prof. Rücker, F.R.S., to serve as an illustration for his lectures on electricity.

Mr. SYMONS doubted if the shaking of the camera would explain the ribbon-like structure of some of the lightning flashes, for if such were the case we must certainly give up all our theories as to the rapidity with which lightning is believed to travel. Although he was disposed to think that lightning was not so rapid in its transit as it was generally thought to be, it would possibly be found that it sometimes travelled at one pace, and sometimes at another. At any rate, the occurrence of ball-lightning showed that lightning sometimes moved at a very slow rate indeed.

Mr. B. WOODD SMITH called attention to the fact that in Turner's pictures lightning was always represented in its natural form, and never by the conventional zig-zag. With regard to the duration of lightning flashes, he had made experiments in night storms with a colour disc rotating about 40 times in a second, and found that when the disc was illuminated by a flash reflected from a cloud, or otherwise than by the direct discharge, the colours were blended as in ordinary daylight, which he attributed to the retention of the light by phosphorescence in the cloud. When it was illuminated by a direct discharge the colours stood out clear and distinct as with an ordinary electric spark, but backed by the disc of blended colour. This retention in ordinary cases by phosphorescence would account for the extreme *sharpness* of distant lightning seen in an absolutely clear sky (as was often the case in Switzerland), there being then nothing to prolong the intrinsic duration of the light. Mr. Smith also described a peculiar striated form of cloud which he said was the invariable precursor of thunder.

Dr. TRIPE remarked that he saw the peculiar appearance of clouds mentioned by Mr. Smith on the afternoon of Wednesday, June 13th, and two thunderstorms occurred on the following day at Hackney. One of these, about 4.10, was severe, although there was only one clap (roar) of thunder and one flash of lightning. In the middle of the clap he heard a loud explosion like the bursting of a large shell, and the lightning (stream) was a broad ribbon-like flash of a blue colour, which descended obliquely, from his point of view, behind some houses, and, as he was informed, ended with a loud explosion by bursting near the ground and giving out arrows of fire. The cloud on the 13th extended across the sky from North-west to South-east, was of a white colour, and showed very clearly against the dark blue sky. The edges were very sharp and straight, the filaments parallel with the edges, and were thinner in some places than others, so that the dark blue sky could be imperfectly seen through it. These also were parallel with the edges of the clouds and with one another. The cloud appeared to be motionless, but it changed its place by passing downwards towards the South-east. Unfortunately he did not watch it until it disappeared, but he saw it for about twenty minutes.

Mr. ABERCROMBY, in reply, said, regarding Prof. Stokes' remarks concerning the engraving of the sparks from Mr. Wimshurst's electrical machine, that it was impossible to get such things satisfactorily reproduced by ordinary engraving processes. The only method which yielded correct results was the photographic. The duplicate flashes appeared to him to be due to reflection, although it was possible that flashes might precisely follow each other. Regarding the dark flash,

he preferred to wait for further evidence before pronouncing any theory as to its cause. The speed at which lightning travelled was hardly known yet, but he believed further investigation would show that the rate of travel varied greatly. He had noticed that the peculiar form of cirro-stratus cloud referred to by Mr. Smith was a precursor of thunderstorms in every part of the world, and had tried to photograph it, but had not yet succeeded.

Ninth Annual Exhibition of Instruments,

PRINCIPALLY THOSE CONNECTED WITH ATMOSPHERIC ELECTRICITY,

Held, by permission of the Council of the Institution of Civil Engineers, at 25 Great George Street, Westminster, S.W.,

MARCH 20TH TO 23RD, 1888.

ELECTROMETERS.

FROM THE ASTRONOMER ROYAL.

1. **Apparatus for Atmospheric Electricity, formerly in use at the Royal Observatory, Greenwich :—**
   1. Bennet's Gold Leaf Electrometer.
   2. Volta's Light Straw Electrometer.
   3. Volta's Heavy Straw Electrometer.
   4. Henley's Electrometer.

   Of these instruments, Nos. 1 to 4, for measure of strength of Electricity, No. 1 is the most sensitive and No. 4 the least sensitive, and they come successively into action as the electrical charge increases.

   5. Zamboni's Dry Piles, for showing the quality of Electricity.
   6. Gourjon's Galvanometer, containing 2,400 coils of fine copper wire, for showing the quality and strength of the electric current.
   7. Ronalds' Spark Measurer, for measuring the length of sparks.

   The above instruments. Nos. 1 to 7, were in use at the Royal Observatory until the year 1877, when Thomson's Quadrant Electrometer for photographic record of atmospheric electricity was introduced. The instruments are mounted so as to show the manner in which they were actually arranged for observation. The exploring copper wire 400 feet long and carefully insulated, extended from the roof of the Octagon Room to the summit of a mast 80 feet high, thence communicating with another wire by which the Electricity was carried to the instruments.

2. **Mascart's Insulator** as employed for insulation of the water cistern in connection with the Thomson Electrometer at the Royal Observatory. (The lower part of the glass vessel contains sulphuric acid.)

FROM THE KEW COMMITTEE.

[NOTE.—The following instruments, Nos. 3–13, were employed by Sir Francis Ronalds in the Electrical Observatory maintained during his superintendence of the Kew Observatory, 1843-1851. A full description of them, with illustrations, is given in the *Report of the British Association* for 1844, the reference number assigned to each instrument being the page of that Report containing its description.]

3. **Volta's Electrometer** with Straws (p. 123).
4. **Gourjon's Galvanometer,** contributed by Sir C. Wheatstone for measuring vertical currrents of Electricity (p. 124).
5. **Various Electrographs or Electrometers,** with modifications arranged by Ronalds (pp. 125 and 138).
6. **Ronalds' Distinguisher** for ascertaining the kind of Electricity possessed by the conductor (p. 125).
7. **Landriani's Electrograph,** as constructed by Ronalds, for recording the presence of Electrical currents, by fixing powdered chalk in the resinous surface of a disc carried round by clockwork. (Incomplete.) (p. 126.)
8. **Calotype Photographic Impression** of one of the records produced by the above (p. 127).
9. **Two Dry Piles,** made by Ronalds.
10. **Wheatstone's Modification of Bennet's Electrometer** (p. 140).
11. **Coulomb's Balance** fitted as an Electrometer by Ronalds. (Incomplete.) (p. 142.)
12. **Insulating Stand** employed by Ronalds to support the collecting rod. (Incomplete.) (p. 122.)
13. **Portable Electrical Observatory** by Ronalds. (Incomplete.)
14. **MS. Vol. of Kew Electrical Observations for 1844.** [Pages 1-3 are printed in Kaemtz's *Meteorology* (Walker's Translation).]
15. **Thomson's Portable Cage Electrometer.** The Electricity was collected by a slow match supported above the observer's head by means of a telescopic holder [not exhibited]. The instrument is described in the *B. A. Report* for 1859, p. 27.
16. **Thomson's Quadrant Electrometer with Replenisher.** This instrument was used, in conjunction with a water-dropping collector, for photographically recording Atmospheric Electricity at the Kew Observatory from 1874 to 1885. It is described with illustrations in the *B. A. Report* for 1867, p. 489.
17. **Thomson's Portable Electrometer.** The Electricity is collected by means of a burning fuse at the extremity of a vertical wire. The instrument has been employed for comparison with the Quadrant Electrometer and for determining the scale value of that, and other similar Electrometers, tested at Kew. It was also lent recently to the Hon. R. Abercromby, F.R.Met.Soc., for his experiments at Teneriffe. An illustrated description is given in the *B. A. Report* for 1867, p. 501.
18. **Two Peltier's Electrometers.** *Exhibited by the* METEOROLOGICAL COUNCIL.
19. **Portable Apparatus for the Observation of Atmospheric Electricity,** by Prof. F. Exner (constructed by H. Schorss, optician, Vienna, V, Kleine Neugasse 13).

    The apparatus is intended for the determination of the Normal Potential in the open air and is portable.

    The chief parts are the following :—

    1. A Leaf Electroscope, in a case, gauged from 50 to 200 volts.
    2. A Holder, with handle to screw on, inlaid with ebony, to carry the collector.
    3. The Collector.

    There are provided, in addition, to calibrate the electroscope afresh, when desired—

    4. A Condenser.
    5. A small Battery of twenty elements.

    Exhibited by Prof. F. EXNER.

LIGHTNING CONDUCTORS.

20. **Specimens of Lightning Conductors sent to the Lightning Rod Conference:—**
    1. Davis and Son's Copper Wire Rope, with hemp centre. Weight, 5 oz. per foot.
    2. Newall's Rope Conductor. Two sizes. Half-inch, weight 6 oz. per foot. Three-eighths inch, weight 3·5 oz. per foot.
    3. Pennycook's Square Drawn Wire Rope. Two sizes. Weight 8 oz. and 6 oz. per foot.
    4. Spratt's Second Patent Conductor. Two sizes. Small, Twelve No. 15 wires and Two No. 18, all copper; weight 3·3 oz. per foot. Large, Eighteen No. 15 wires and Two No. 18; weight 5·2 oz. per foot.
    5. Vyle's Patent Conductor. This has a central insulated wire to be used for testing the continuity of the conductor.

    Exhibited by the LIGHTNING ROD CONFERENCE.

21. **Model of Church,** showing Messrs. J. W. Gray & Son's system of continuous copper band Lightning Conductors.
    Exhibited by Messrs. J. W. GRAY & SON.

22. **Model of House,** showing the same system, by surrounding all the chimneys with copper bands brought down along the ridge, and the whole connected to a main conductor taken down to ground, with a copper plate at foot. *Exhibited by* Messrs. J. W. GRAY & SON.

23. **Model of Chimney-Shaft,** showing the same system, having a copper band round the top and copper points throughout the circumference, the rod being connected with all bands and metallic masses in or near the chimney. *Exhibited by* Messrs. J. W. GRAY & SON.

24. **Specimens of Lightning Conductors and accessories used in fitting:—**
    1. Full sized copper rings with 4 points to each, for factory chimneys.
    2. Lightning rod terminals with plates.
    3. Copper connecting clamp with 4 points, as fitted to iron finials.
    4. Copper connections for tops of shafts.
    5. Copper connecting pieces for ridges.
    6. Copper spindle plates.
    7. Various sized copper straps for fastening tape.
    8. Copper nails.
    9. Copper plugs for stone-work at top of chimney shafts.
    10. Copper holdfasts for building in brick-work while in the course of erection.
    11. Copper holdfasts fitted in bricks, showing the system of fixing the same.
    12. Four samples of copper tape, 1 in., 1¼ in., 1½ in., and 2 in.
    13. Single pointed terminals. *Exhibited by* Messrs. J. W. GRAY & SON.

25. **Galvanometer** for testing the continuity, &c. of Lightning Conductors.
    Exhibited by Messrs. J. W. GRAY & SON.

26. **Model of Church** showing system of Lightning Conductors.
    Exhibited by Messrs. R. ANDERSON & Co.

27. **Model of Top of Chimney Shaft** showing mode of fixing upper terminals.
    Exhibited by Messrs. R. ANDERSON & Co.

28. **Samples of Copper Tape and Copper Rope Lightning Conductors.**
    Exhibited by Messrs. R. ANDERSON & Co.

29. **Coil of Copper Tape,** 300 feet long.
    Exhibited by Messrs. R. ANDERSON & Co.

30. **Various Forms of Points and Rods;** also Couplings, Clips and other fastenings. *Exhibited by* Messrs. R. ANDERSON & Co.

31. **Copper Lightning Conductors,** Specimens of Tape and Rope.
    Exhibited by Messrs. J. DAVIS & SON,

32. **Copper Lightning Rod Terminals,** with silvered points and accessories.
Exhibited by Messrs. J. Davis & Son.

33. **Lightning Rod Testing Apparatus.**—This consists of a magneto-inductor in combination with a testing-board, on the principle of Wheatstone's bridge. It is fitted with a galvanometer and other testing appliances, which are all contained in one portable case, and are capable of being used by persons who have no knowledge of electricity. By means of the inductor, magneto-electric currents are sent through the lightning-rod and earth connection, and the resistance of these is shown on the testing-board. If this be above 10 ohms, the conductor or earth connection is faulty, and should be at once repaired, as the conductor, instead of being of a source of a safety, has become a source of danger to the building.
Exhibited by Messrs. Siemens Brothers & Co.

34. **Model of a Section of a Ship Fitted with Lightning Conductor.**
Exhibited by Messrs. J. W. Gray & Son.

LIGHTNING PROTECTORS FOR TELEGRAPH PURPOSES.

From the Postal Telegraph Department, per W. H. Preece, F.R.S.

35. **Twisted Wire Reel Protector, 1878.** Consists of two wires insulated with silk, one connected to the line, and the other to earth, twisted together and wound on a boxwood reel.

36. **Varley's Vacuum Protector, 1880.** Consists of two points a short distance apart, enclosed in a small glass bulb exhausted of air. One point is connected to the line and the other to earth.

37. **Varley's Boxwood and Carbon Protector, 1878.** Consists of two metal points in a small chamber in a small cylinder of boxwood. The chamber is filled with powdered carbon, which is non-conducting to the working current, but conducts the high tension electricity due to a lightning discharge.

38. **Tube Protector, 1880.** Consists of two wires insulated with silk, connected one to the "up" and the other to the "down" line, wound together on a brass cylinder connected to earth; a brass tube, also connected to earth, encloses the whole.

39. **Smaller Pattern** of No. 38.

40. **Varley's Globe Vacuum Lightning Protector, 1861.**—A number of platinum points connected to the line-wire are arranged in close proximity to the end of a platinum wire connected to earth, the whole being enclosed in a small glass globe (through which the wires pass, and into the sides of which the wires are sealed) exhausted of air.

41. **Siemens's Plate Protector, 1865.**—Consists of two corrugated cast-iron plates, the upper one connected to line and the lower one to earth. The plates are prevented from touching each other by their ebonite washers. The corrugations on the plates are so cut that those on the one plate are at right angles to those on the other.

42. **Plate Protector, 1880.**—Similar in general arrangement to No. 41, but with the plates separated by a square frame of thin mica.

43. **Double Plate Protector, 1875.**—A protector for intermediate stations; one plate is connected to the "up" and the other to the "down" line. The plates are separated from the earth plate, on which they rest, by thin paraffined paper.

44. **Small Form of Plate Protector.**

45. **Modern Circular Plate Protector, 1886.**—The plates, which are of small dimensions and circular in form, are separated by a thin sheet of mica, which has three circular perforations in it.

46. **Cable Protector, 1870.**—Used at the junction point of a submarine cable with a land line. It consists of a corrugated plate protector similar to No. 42, and also of a silk-covered german-silver wire, on circuit with the line, wound on a metal bobbin connected to earth, the whole being covered with paraffin-wax to keep out moisture.

47. **Cable Protector, 1880.**—Similar to No. 46, but with the plates uncorrugated, experiment having proved that corrugations did not increase the efficiency of the arrangement.

OBJECTS DAMAGED BY LIGHTNING, &c.

48. **A Man's Clothes, torn off his body by Lightning** on June 8th, 1878, while standing under a Tree, comprising Cotton Jacket, Flannel Under-vest, Trousers, Stockings, Garters, Boots, and Watch: also a portion of the Bark from the Tree. (This case is fully described in a Paper by Dr. G. Wilks, of Ashford, in the *Transactions of the Clinical Society of London*, Vol. XIII. p. 32.)
Exhibited by the ROYAL COLLEGE OF SURGEONS.

49. **A Lightning Conductor which failed** at Caterham, May 28th, 1879, consisting of, 1. Upper terminal; 2. Screwed union at which the conductor was fused; and 3. Portion of conductor (Spratt's first patent, thirteen plaited copper wires and one zinc one). With photograph.
Exhibited by the LIGHTNING ROD CONFERENCE.

50. **A Lightning Conductor** taken from the Royal Hospital for Incurables, Putney, August 13th, 1880.
Exhibited by the LIGHTNING ROD CONFERENCE.

51. **Wire Conductor** taken from Messrs. Courage's Brewery, June 28th, 1881.
Exhibited by the LIGHTNING ROD CONFERENCE.

52. **Sample of Copper Lightning Conductor destroyed by Lightning.**
Exhibited by Messrs. J. W. GRAY & SON.

53. **Damaged Conductors.** *Exhibited by* Messrs. R. ANDERSON & Co.

54. **Section of Barrel of Walker's Protector of Telegraph Instruments,** showing lightning discharge.
Exhibited by W. LEONARD, of S. E. Railway.

55. **Siemens's Protector, from an Underground Circuit** damaged in thunderstorm August 17th, 1887. *Exhibited by* W. LEONARD, of S. E. Railway.

56. **Walker's Signal Ball,** showing lightning discharge across the brass bobbins and partial rupture of copper wire.
Exhibited by W. LEONARD, of S. E. Railway.

57. **Telegraph Line Wire fused by Lightning** at Stornoway, May 1st, 1884.
Exhibited by the POSTAL TELEGRAPH DEPARTMENT.

58. **Specimens showing the effects of Lightning on Trees.**
Exhibited by Prof. D. COLLADON.

59. **Portions of a Rafter** shattered in a roof at Kentish Town by Lightning, in June 1883. *Exhibited by* G. J. SYMONS, F.R.S.

60. **Pieces from an Oak Tree** in Richmond Park, struck by Lightning on August 6th, 1885. *Exhibited by* G. J. SYMONS, F.R.S.

61. **Pieces of Wood and Bark** from a tree in the Green Park, struck by Lightning on August 17th, 1887.
Exhibited by Capt. H. TOYNBEE, F.R.Met.Soc.

62. **Splinters from an Elm Tree** at Harbour View, four miles to the South of Waterford, struck by Lightning on August 17th, 1887. The bark and 3 to 4 inches deep of the wood were torn off the bole of the tree for about 20 feet, and two pits formed in the ground at its base in the direction of the main roots.

Exhibited by R. J. LECKY, F.R.Met.Soc.

63. **Solar Radiation Thermometer,** with the inner bulb broken during the Hailstorm of August 3rd, 1879, at the Kew Observatory. (See *Quarterly Journal*, Vol. VI., p. 50.) *Exhibited by the* KEW COMMITTEE.

ALLEGED THUNDERBOLTS.

64. **Meteoric Iron,** which fell at Bitburg, 16 miles north-north-west of Treves, Germany, in 1805. *Exhibited by* G. J. SYMONS, F.R.S.

65. **Meteoric Iron,** from Seneca Falls, New York. Shows Widmanstätten figures. *Exhibited by* G. J. SYMONS, F.R.S.

66. **Meteoric Iron** found near the Great Fish River, Cape of Good Hope. (See *Exotic Mineralogy*, by James Sowerby, Vol. II. p. 137, 1817.)
Exhibited by W. SOWERBY, F.R.Met.Soc.

67. **Meteorite, Earthy,** which fell at Montrejeau, Haute Garonne, France, December 9th, 1858. *Exhibited by* G. J. SYMONS, F.R.S.

68. **Meteor-Stone and Iron,** which fell at Knyahinya, Hungary, June 9th, 1866.
Exhibited by G. J. SYMONS, F.R.S.

69. **Alleged Thunderbolt** which is reported to have fallen in the Park surrounding Casterton Hall, Westmoreland, during a Thunderstorm. This is said to have been seen to fall by the late Rev. W. Carus-Wilson, his wife and three daughters, and that it fell under a large tree and killed a sheep. The report states that it penetrated the ground for about 6 feet, and when afterwards dug out was quite hot. In appearance it much resembles a volcanic bomb.

This is really a nodular concretion of sandstone, but was doubtless found in the hole made by the lightning flash.

Exhibited by C. CARUS-WILSON, F.G.S.

70. **Cannon Ball,** from the analysis of which it is believed to be made of old Sussex Iron, found at the bottom of a hole in a manure heap after a flash of lightning had struck near it.

Lent to and exhibited by G. J. SYMONS, F.R.S.

71. **Specimens of Iron Pyrites.** So-called "Thunderstones."
Exhibited by G. J. SYMONS, F.R.S.

72. **Specimens of Belemnites.** *Exhibited by* G. J. SYMONS, F.R.S.

73. **Alleged Thunderbolt,** from Westbourne Park, Notting Hill, June 30th 1866. This is a piece of coal. *Exhibited by* G. J. SYMONS, F.R.S.

74. **Clinkers from a Fire Engine** from Kilburn, July 5th, 1877.
Exhibited by G. J. SYMONS, F.R.S.

NEW INSTRUMENTS.

75. **Maximum Wind Pressure Instrument.**—The pressure of the wind forces back the plate, and thus allows shot to fall from the higher to the lower vessel. As soon as the weight of the shot in the lower vessel is equal to the whole pressure on the plate, the plate resumes its normal position, and the opening through which the shot falls is closed.

To read the Instrument.—Remove the cover from the higher vessel, and fasten back the plate by means of the hinge which is inside, then by means of the glass-measuring vessel raise the valve at the bottom of the lower vessel and allow the shot to fall in the glass. The weight of shot in the glass then gives the maximum pressure since the instrument was last read. *Exhibited by* W. H. DINES, F.R.Met.Soc.

76. **Recknagel's Electric Anemometer.**—(The counter is lent by Mr. Walter Baily.) *Exhibited by the* METEOROLOGICAL COUNCIL.

77. **Rain-band Spectroscope, Tripe's Arrangement.**—The improvements in this instrument, over the ordinary form of direct vision Spectroscope, are, 1. That it gives uniform light and dispersion, and also better definition of the lines; 2. That as the slit is of uniform width, observations made with this form of instrument are comparable with each other; and 3. That the focussing tube can be fixed by a revolving clamp and kept ready for use, and also immediately rendered moveable by a half-turn of the revolving clamp, and fixed again to suit the sight of any observer. *Exhibited by* G. H. LARKINS.

78. **Simple Form of Portable Barometer.**—This instrument consists of a glass tube, about 19 inches long, of uniform calibre, of from 1 to 2 mm. internal diameter, and hermetically closed at one end. The tube contains a continuous thread of mercury 10 inches long, and between this mercury and the closed end of the tube is a cushion of air, which, at ordinary pressures and temperatures, is about 5 inches long. The tube is fixed on wood, and is graduated with a scale of equal parts, having its zero coincident with the closed end of the tube. At each end of the mounting there are fixed rings, by which to hang the instrument, either end upwards, on a nail in a wall. The method of finding the barometric height is as follows:—1. A reading x is taken of the end of the mercury thread nearest to zero, when that end is *upwards*. 2. A reading y is taken of the same end of the mercury thread, when that end is *downwards*. The fraction $\frac{x+y}{x-y}$ represents the height of the barometer in terms of the length of the thread of mercury, and therefore merely requires to be multiplied by the length of the thread in inches to give the barometric height in inches. *Exhibited by* T. H. BLAKESLEY.

79. **Colladon's Instrument for Illustrating the Formation of Waterspouts.** *Exhibited by* Dr. W. MARCET, F.R.S., President.

80. **Colladon's Instrument for Determining the Temperature of Hail.** *Exhibited by* Dr. W. MARCET, F.R.S., President.

81. **Repeating Cloud Camera,** designed by Mr. Whipple, for obtaining a series of four Photographs of the same cloud at short intervals of time, in order to show rapid changes of form. *Exhibited by the* KEW COMMITTEE.

82. **Schanschieff Electric Lamp.**—This Lamp is suitable for use in taking meteorological observations. It contains a hermetically sealed battery, which, when charged and not in use, will remain for a length of time without consumption of material or loss of energy. When the light is required it is only necessary to reverse the position of the lamp, by which motion the battery elements become immersed in the solution, and the lamp is brought to incandescence. Again reversing its position the lamp is put at once out of action.

Exhibited by the SCHANSCHIEFF ELECTRIC BATTERY SYNDICATE.

83. **Jordan's Photographic Sunshine Recorder.** New pattern.
Exhibited by J. B. JORDAN.

84. **Photographic Sunshine Recorder,** devised by Dr. J. Maurer, of the Swiss Central Observatory, Zurich. *Exhibited by* J. B. JORDAN.

85. **Self-Recording Aneroid,** arranged to give a continuous trace.
Exhibited by J. C. PHILIPS.

85.* **Small Model of the Kite** portion of Archibald's Patent Kite Balloon, adapted for exploring Atmospheric Electricity. With the balloon this apparatus may be kept up in either a light or strong breeze, thus combining the advantages of both kite and balloon.
Exhibited by E. D. ARCHIBALD, F.R.Met.Soc.

PHOTOGRAPHS OF FLASHES OF LIGHTNING.

86. **1881, July 5th,** 10.0 to 10.5 p.m., Brighton.
87. **1884, August 9th,** Tynemouth. Two photographs. Taken by M. Auty.
88. **1886, July —,** 11.30 p.m., Ramsgate. Taken by G. F. Harvey.
89. **1886, October 6th,** Midnight, Bournemouth. Taken by Dr. Drewitt.
90. **1887, August 17th,** 7.35 p.m., Bloomfield Terrace, Pimlico, London. Taken by G. C. Baker.
91. **Do.** 8 p.m., London. Two photographs. Taken by E. A. Barton.
92. **Do.** 8.15 p.m., Mitcham Road, Streatham. Taken by J. H. Bateman.
93. **Do.** 9 p.m., Putney. Taken by A. W. Bates.
94. **Do.** Croydon. Five photographs. Taken by G. Corden.
95. **Do.** 9 p.m., Brixton. Taken by J. Gray.
96. **Do.** Battersea. Taken by G. J. Ninnies.
97. **Do.** Regent Street, London. Taken by Messrs. J. Robinson and Sons.
98. **Do.** Westbourne Grove, W., London. Eight photographs. Taken by E. S. Shepherd.
99. **Do.** 8 p.m., Belsize Park, London, N.W. Three photographs. Taken by W. Shuter.
100. **Do.** 7.30 p.m., Highbury. Taken by Capt. A. S. Thomson.
101. **Do.** Wandsworth. Taken by C. H. Wordingham.

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102. **1884, July 12th,** 8 p.m., Mount Vernon, New York. Two photographs. Taken by G. R. Allerton.
103. **1885, August 1st,** 10.30 p.m., Philadelphia. Taken by W. N. Jennings.
104. **1886, April —,** Pittsburg, Pennsylvania. Taken by L. S. Clarke.
105. **1886, July,** 8.30 p.m., Greenwich, Connecticut. Two photographs. Taken by Dr. H. G. Pippard.
106. **1887, June 22nd,** 2.30 a.m., Philadelphia. Taken by W. N. Jennings.
107. **1887, July 17th,** 10 p.m. and 10.40 p.m., Dubuque, Iowa. Two photographs. Taken by G. E. Davis.
108. **Do.** 10.30 p.m. and 10.40 p.m., Irvington-on-Hudson. Two photographs. Taken by R. H. Lawrence.
109. **1887, August 2nd,** Top of Alleghany Mountains, Pennsylvania. Two photographs. Taken by L. S. Clarke.

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110. **1886, May 26th,** 10.30 p.m., Rougemont, near Tours, France. Taken by H. Schleusner and E. B. Vignoles.

111. **1887, June 25th,** Auteuil, Paris. Three photographs. Taken by C. Moussette.

112. **1887, July 13th-14th,** Fontainebleau. Forwarded by Mons. Willy.

113. **1884, November 14th,** 6.30 p.m., on board H.M.S. *Neptune*, between Madeira and Gibraltar. Taken by Dr. Puddicombe, R.N.

114. **1885, October —,** 9 p.m., Amzinto, Natal. Taken by R. Harris.

115. **1887, March, 15th,** Calcutta. Taken by G. L. Molesworth.

The above, Nos. 86 to 115, were received in response to the Circular issued by the Royal Meteorological Society in June, 1887, asking for Photographs of Flashes of Lightning.

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116. **1886, May 12th,** Auteuil, Paris, Photograph, and Enlargements.
Exhibited by C. MOUSSETTE.

117. **1887, August 17th,** Westbourne Grove, London. Seven photographs, and three Enlargements. *Exhibited by* E. S. SHEPHERD.

118. **Diagrams of Lightning, by Mr. James Nasmyth, F.R.S.,** made in 1856, showing: 1, Nature's Lightning; 2, Painter's Lightning; and 3, Forked Lightning. (See *B. A. Report* for 1856, p. 14.)
Exhibited by G. J. SYMONS, F.R.S.

PHOTOGRAPHS, DRAWINGS, &c.

119. **Eight Photographic Enlargements of Drawings of Hailstones.**
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

120. **Electrograms and Barograms** taken at the Kew Observatory, on August 17th, 1887, showing the electric and barometric disturbances accompanying the Thunderstorms which occurred on that day.
Exhibited by the KEW COMMITTEE.

121. **Diagram of Diurnal and Annual Changes of Atmospheric Potential** at the Kew Observatory. (See *B. A. Report* for 1881, p. 443).
Exhibited by the KEW COMMITTEE.

122. **Photographic Record of Atmospheric Electricity,** by Thomson's Electrometer, with corresponding record of Barometer, showing disturbed condition of the atmosphere during a Thunderstorm on the morning of May 22nd, 1886, at the Royal Observatory, Greenwich.
Exhibited by W. H. M. CHRISTIE, F.R.S., Astronomer Royal.

123. **Photographic Record of Atmospheric Electricity,** by Thomson's Electrometer, from noon, 26th, to noon 27th December, 1886, showing disturbance of the electrical condition of the atmosphere during a snowstorm.
Exhibited by W. H. M. CHRISTIE, F.R.S., Astronomer Royal.

124. **Three Diagrams showing the Diurnal Inequality of Atmospheric Electricity** as derived from the photographic records of Thomson's Electrometer for the years 1879 to 1886. The diurnal inequality, for rainy and for non-rainy days, is also given for the years 1882 to 1886.
Exhibited by W. H. M. CHRISTIE, F.R.S., Astronomer Royal.

125. **Photograph of Chimney** of East London Water Works at Old Ford, in process of being fitted with Lightning Conductor.
Exhibited by Messrs. J. W. GRAY & SON.

126. **Photograph of Hereford Cathedral,** fitted in 1887 with Lightning Conductors, in accordance with the rules of the Lightning Rod Conference.
Exhibited by Messrs. J. W. GRAY & SON.

127. **Lithograph of Church Steeple, at Blackrock, near Cork,** struck by Lightning on January 29th, 1836.
Exhibited by R. J. LECKY, F.R.Met.Soc.

128. **Photograph of Wells Church, Norfolk,** ignited by Lightning, August 2nd, 1879. *Exhibited by* G. J. SYMONS, F.R.S.

129. **Photograph of Shoes of Children** struck by Lightning in Atcham Church, Shrewsbury, July, 1879. *Exhibited by* G. J. SYMONS, F.R.S.

130. **Photograph of Arm of a Boy** struck by Lightning, at Dunse, Berwickshire, June 9th, 1883, showing the arborescent markings. (See *Glasgow Medical Journal*, Vol. XX., p. 321.) *Exhibited by* G. J. SYMONS, F.R.S.

131. **Photograph of large Poplar** in grounds of St. John's Lodge, Regent's Park, struck by Lightning on July 6th, 1881.
Exhibited by G. J. SYMONS, F.R.S.

132. **Oak Trees in Richmond Park struck by Lightning** on August 6th, 1885, photographed by Mr. Hugo, Assistant at the Kew Observatory. (See *Nature*, Vol. XXXII., p. 460), *Exhibited by* THE KEW COMMITTEE.

133. **Two Photographs of Oak in Richmond Park** struck by Lightning, on August 6th, 1885, taken by Mr. Seeley.
Exhibited by G. J. SYMONS, F.R.S.

134. **Photographs of Oak** shattered by Lightning, East Tisted, Alton, Hants, May 20th, 1887. *Exhibited by* Rev. F. HOWLETT, F.R.A.S.

135. **Photograph of part of the Alleged "Thunderbolt,"** reported to have fallen at Kilburn during the Storm on July 5th, 1877.
Exhibited by G. J. SYMONS, F.R.S.

136. **Small Fulgurite. Natural size.** Dug out in the Dresdener Haide by Berg-Commissary Dr. G. Fiedler in 1820, and put together by G. Fiedler in 1856. *Exhibited by* G. J. SYMONS, F.R.S.

137. **Large Fulgurite. Natural size.** "June 13th, 1841.—The Lightning struck in a vineyard belonging to Madame von Gulschmidt, about 50 yards south of the cottage which the immortal Schiller tenanted for a time, and where he wrote his "Don Carlos." The Fulgurites formed in the sand were, by kind permission of the proprietress, dug out and put together by my late father. One of these is in the British Museum, for which it was purchased in 1851. It is the only complete one which exists in any public collection. This, of which I give a sketch, is a similar one and is in my possession, and I am quite ready to give all information as to its discovery, &c. The original descriptions of such Fulgurites by my late father, Karl Gustav Fiedler, are in Gilbert's and Poggendorff's *Annals* from 1817 to 1823.—GUSTAV FIEDLER."
Exhibited by G. J. SYMONS, F.R.S.

138. **Photograph of the Computing Room** of the Magnetical and Meteorological Department, Royal Observatory, Greenwich, showing in the window the instruments used for measuring atmospheric electricity in 1871.
Exhibited by W. MARRIOTT, F.R.Met.Soc.

139. **Four Photographic Views of the New Thermograph** of the Royal Observatory. *Exhibited by* W. H. M. CHRISTIE, F.R.S., Astronomer Royal.

140. **Photographic Record of the Dry Bulb and Wet Bulb Thermometers** from noon 7th to noon 8th December, 1887, as given by the New Thermograph, at the Royal Observatory.
Exhibited by W. H. M. CHRISTIE, F.R.S., Astronomer Royal.

141. **Temperature Curve taken by a Draper Recording Thermometer** at Blue Mountain Lake, New York State, for the week ending January 24th, 1888. This curve shows a temperature of —29° which occurred on January 22nd. *Exhibited by* THE DRAPER MANUFACTURING COMPANY.

142. **Photographs of Instruments in use at Sydney Observatory, New South Wales.**
1. Thermometer Shed in use since 1866.
2. Barograph.
3. Recording parts of Anemometer and Rain-gauge.
4. Self-recording Anemometer for country stations in New South Wales.
5. Recording parts of ditto.

Exhibited by H. C. RUSSELL, F.R.S.

143. **Two large Photographs** taken from the top of the Worcestershire Beacon (1,390 feet above sea-level), about 700 feet above the general level of the fog which covered the whole of the surrounding country, at 1.30 p.m. on January 12th, 1888. Above the fog there was bright sunshine, and a cloudless sky.
Exhibited by Messrs. NORMAN MAY AND Co., Limited.

144. **Four Photographs of Clouds.** *Exhibited by* C. MOUSSETTE.

145. **Photographs of Clouds** taken in or near Teneriffe, October, 1887.
Exhibited by the Hon. R. ABERCROMBY, F.R.Met.Soc.

146. **Photographs of Clouds** taken during 1887.
Exhibited by the Hon. R. ABERCROMBY, F.R.Met.Soc.

147. **Eight enlarged Photographs of Clouds.**
Exhibited by the Hon. R. ABERCROMBY, F.R.Met.Soc.

148. **Cloud Photographs** taken at the Kew Observatory with the Repeating Cloud Camera. *Exhibited by the* KEW COMMITTEE.

149. **The Chromatics of the Sky.** Sketches of Skies in colour, from nature, 1887-88, with barometrical, thermometrical, and other observations taken simultaneously with the sketches for the object of showing that the "Chromatics of the Sky" may be used as factors in assisting in the forecasts of weather. (Sixth Series).
Exhibited by J. S. DYASON, F.R.Met.Soc.

150. **Krakatoa in eruption, May, 1883.** Reproduced from a photograph taken and coloured by a Batavian artist on board a steamer. Lent by Mr. G. A. J. Cole, Science and Art Department, South Kensington.
Exhibited by J. S. DYASON, F.R.Met.Soc.

151. **Photographic Views of Lake George, New South Wales.**
Exhibited by H. C. RUSSELL, F.R.S.

152. **Photographic Views of the Darling River, New South Wales,** showing the river during the great drought of 1885, and in flood during 1886.
Exhibited by H. C. RUSSELL, F.R.S.

153. **Monthly Percentages of Rainfall, 1866-80.** Twelve charts of the British Isles, showing the percentage of the annual fall which occurs in each month. Also two charts showing the months of maximum and of minimum fall respectively. *Exhibited by* H. MELLISH, F.R.Met.Soc.

154. **Diagrams of Annual Rainfall in South Africa, 1850-1886.**
Exhibited by W. B. TRIPP, F.R.Met.Soc.

WILLIAM MARCET, M.D., F.R.S., *President.*
G. J. SYMONS, F.R.S.
JOHN W. TRIPE, M.D. } *Secretaries.*
WILLIAM MARRIOTT, *Assistant Secretary.*

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

MARCH 21ST, 1888.

Ordinary Meeting.

WILLIAM MARCET, M.D., F.R.S., President, in the Chair.

GEORGE EDWARD SCHOLEFIELD, M.D., 253 Lytham Road, Blackpool; and
Col. WILLIAM SIDDONS YOUNG, 3 Promenade, Great Malvern,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"ADDRESS ON ATMOSPHERIC ELECTRICITY." By WILLIAM MARCET, M.D., F.R.S., President. (p. 197.)

"THE NON-EXISTENCE OF THUNDERBOLTS." By G. J. SYMONS, F.R.S., Secretary. (p. 208.)

On the motion of Mr. LATHAM, seconded by Mr. BREWIN, the thanks of the Society were given to the Exhibitors for the loan of their Instruments, &c.

The Meeting was then adjourned in order to afford the Fellows an opportunity of inspecting the Exhibition of Instruments, principally connected with the record of Atmospheric Electricity, which had been arranged in the rooms of the Institution of Civil Engineers. The List of Exhibits will be found on p. 234.

APRIL 18TH, 1888.

Ordinary Meeting.

WILLIAM MARCET, M.D., F.R.S., President, in the Chair.

THOMAS EGERTON HALE, M.C., B.A., M.D., Faddiley Lodge, Nantwich;
ROBERT LAWSON, LL.D., F.S.S., 20 Lansdowne Road, W.; and
SAMUEL WALKER, 22 Moorgate Street, E.C.,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"JORDAN'S NEW PATTERN PHOTOGRAPHIC SUNSHINE RECORDER." By JAMES B. JORDAN. (p. 212.)

"ON THE METEOROLOGY OF SOUTH-EASTERN CHINA IN 1886." By WILLIAM DOBERCK, Ph.D., F.R.Met.Soc. (p. 217.)

"LIGHTNING IN SNOWSTORMS." By Prof. A. S. HERSCHEL, M.A., D.C.L., F.R.S. (p. 222.)

"INSOLATION." By RUPERT T. SMITH, M.Inst.C.E., F.R.Met.Soc. (The publication of this Paper is deferred.)

CORRESPONDENCE AND NOTES.

RAINFALL IN CHINA IN 1887. By William Doberck, Ph.D., F.R.Met.Soc.

Station.	Lat. N.		Long. E. Greenwich.		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
	°	′	°	′	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Yuensan	39	9	127	33	7·33	..	·63	4·13	2·52	2·67	5·59	29·43	5·98	·55	·79	..	59·62
Houki	38	4	120	39	..	..	·87	·32	3·94	·06	·60	2·52	1·46	·96	1·42	·22	12·37
Chefoo	37	34	121	32	3·15	·01	·34	1·11	1·85	·18	1·95	4·85	·90	1·00	·42	..	15·76
Chemulpo	37	29	126	37	1·37	..	·52	3·40	1·13	3·68	4·52	12·25	1·71	·99	1·79	1·09	32·45
Shangtung Promontory	37	24	122	42	1·39	..	·09	2·50	2·02	·16	1·46	5·24	1·51	·62	·91	·62	16·52
Fusan	35	5	129	6	5·00	..	·48	4·26	3·10	1·34	3·99	2·68	8·76	5·60	·64	·02	35·87
Chinkiang	32	12	119	30	1·56	1·06	1·40	2·08	5·60	3·90	3·42	2·53	2·38	1·05	·26	·16	25·40
Wusung	31	25	121	27	7·38	1·69	1·34	1·36	3·55	10·39	6·56	1·18	10·79	·38	·28	·11	45·01
Shaweishan	31	25	122	15	9·12	2·10	1·06	·93	3·26	10·23	5·16	·40	4·38	1·16	·23	..	38·03
Wuhu	31	22	118	22	7·14	1·47	3·72	1·99	5·55	16·20	1·64	·77	1·49	1·66	·20	·08	41·91
North Saddle	30	52	122	40	10·06	1·16	1·13	·69	3·68	10·02	4·49	·05	2·12	1·28	·19	..	34·87
Gutzlaff	30	49	122	11	6·40	·87	1·48	·29	2·85	11·77	5·58	..	·88	1·18	..	·20	31·50
Hankow	30	33	114	20	6·78	1·46	3·20	2·23	12·82	32·28	4·05	3·27	·48	1·70	·35	·06	68·68
Ichang	30	12	111	19	3·49	·67	1·88	1·55	7·44	9·80	11·15	3·95	·73	1·88	1·34	·17	44·05
Steep Island	30	12	122	36	3·54	1·48	1·41	1·09	2·68	16·58	2·10	·12	3·47	1·77	·38	..	34·62
Ningpo	29	58	121	44	11·37	5·13	4·12	3·13	5·50	19·12	8·00	4·75	8·62	4·63	..	·25	74·62
Kiukiang	29	43	116	7	6·74	2·73	2·99	3·04	10·60	16·92	2·81	1·39	·48	·89	·58	·38	49·55
Winchow	28	0	120	35	2·47	1·11	2·04	2·16	4·34	21·75	9·90	3·00	6·67	·50	..	..	53·94
Foochow	26	8	119	38	6·50	1·34	3·97	3·76	2·95	2·07	9·72	·20	5·53	·79	..	..	36·83
Middle Dog	25	58	120	2	6·09	1·31	3·99	2·69	2·77	·90	4·64	·51	8·39	·86	·34	..	32·49
Turnabout	25	26	119	59	6·00	1·04	2·62	2·57	5·05	1·26	6·50	..	3·21	·51	·58	·14	29·48
Tamsui	25	10	121	25	6·66	5·47	7·89	5·03	4·69	·38	13·13	1·96	8·15	8·99	2·19	1·74	66·28

RAINFALL IN CHINA IN 1887—*Continued.*

Station.	Lat. N.	Long. E. Greenwich.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
	° ′	° ′	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Keelung	25 8	121 45	21·27	19·95	15·43	8·52	9·58	4·09	20·05	2·81	13·09	4·21	9·22	8·57	136·79
Ockseu	24 59	119 28	4·45	·66	3·54	1·77	2·42	·82	2·94	·05	·04	·15	·21	..	17·05
Amoy	24 27	118 4	6·20	1·30	4·21	2·44	2·25	1·27	8·41	7·61	3·98	·65	·34	..	38·66
Chapel Island	24 10	118 13	7·93	3·47	5·45	2·36	4·19	3·02	3·18	6·25	3·41	·45	·29	..	40·00
Fisher Island	23 33	119 28	1·72	1·49	2·64	1·23	·85	·19	5·40	1·90	·56	..	·35	·24	16·57
Swatow	23 20	116 43	8·28	1·64	2·71	1·99	3·07	1·71	7·66	7·91	7·33	2·35	·73	·02	45·40
Lamocks	23 15	117 18	4·00	1·11	2·04	3·18	1·45	·62	4·64	7·22	4·19	1·41	·37	·18	30·41
Canton	23 7	113 17	5·63	2·10	5·60	3·70	9·35	3·49	7·47	7·75	13·25	2·25	·40	·12	61·11
Anping	22 59	120 13	·16	·71	2·54	1·01	1·58	4·23	14·49	6·94	5·16	..	1·15	·78	38·75
Breaker Point	22 56	116 28	5·37	·49	2·30	1·62	1·35	1·08	6·34	10·45	8·42	2·26	·84	·36	40·88
Takow	22 36	120 16	..	·34	3·32	·63	·64	5·33	14·49	10·88	5·94	..	·51	1·32	43·40
Hongkong	22 18	114 10	8·43	1·89	2·95	5·64	2·05	5·47	12·08	13·15	10·96	2·03	·79	·85	66·29
South Cape	21 55	120 51	1·59	2·09	6·65	1·65	2·00	4·63	22·80	17·94	14·24	1·11	·18	2·46	77·34
Pakhoi	21 29	109 6	2·99	..	1·83	·48	5·67	3·16	17·12	19·11	12·37	..	·60	·45	63·78
Kiungchow	20 3	110 20	3·10	2·10	1·20	1·60	5·30	3·30	10·60	7·70	13·20	5·30	·50	1·10	55·00

The Rainfall is greatest along the East Coast of Formosa and least on small isolated islands, which latter fact is easily explained by the circumstance that they do not force the air to ascend by obstructing its horizontal progress, as is the case with mountains, for which reason *e.g.* the rainfall at Victoria Peak, 1,700 feet above the Hongkong Observatory, is one-sixth greater than at the latter station. Practically all the gauges are near the level of the sea. The highest is on Gutzlaff, which is about 250 feet above the sea-level, but there is not more rain collected there than at other stations. The rainfall was small in Northern China, but much greater in the Corea. This year the rainfall was abnormally great in January, which is usually the driest month next to November and December, and this obtained nearly everywhere in China.

The Production of Hoarfrost.

Among the papers on agricultural meteorology emanating from the Agricultural Laboratory at Munich, a paper on the above subject by Prof. Dr. Wollny is especially interesting. Dr. Wollny tested a rule which he attributes to Lang, but which we believe was stated long ago by Mr. Buchan, viz. that if the dew-point is not below the freezing point in the evening, there is not much fear of hoar-frost during the succeeding night.

Dr. Wollny compared the dew-point at 5 p.m. with the succeeding night minimum for the 6 months, April to September inclusive, in 1887. His results are thus stated:—1. The dew-point calculated from the dry and wet bulb readings at 5 p.m. rarely coincided with the nocturnal minimum. 2. The fact that the minimum fell below 32° was rarely indicated by the dew-point—in fact only 6 times out of 17. The reason of this failure is mainly to be found in the fact that the dew-point determinations have no relation to the conditions of terrestrial radiation.

Kammermann's theory is that the difference between the wet bulb reading, even at 1 p.m., and the succeeding night minimum is constant throughout the year.[1] Dr. Wollny finds that it gives somewhat better results than the dew-point system, but is not really trustworthy.

Dr. Wollny concludes by saying that no infallible rule has yet been proposed for prediction of these frosts, and that as to protection against their influence the generation of smoke in large quantities is impracticable over open fields. As regards orchards or vineyards, he recommends a plan proposed by M. Lestelle, Director of Telegraphs in Mont de Maisan (Dept. Landes). This is to have an automatic thermometric arrangement. The thermometer closes a voltaic circuit when the temperature falls to a certain point, a current is set up, and this is caused to set fire to heaps of weeds, &c. previously placed at the spots where the action of the smoke will be most efficacious.

RECENT PUBLICATIONS.

American Meteorological Journal. April-June 1888. 8vo.

The principal articles are:—The organisation of the meteorological service in some of the principal countries of Europe, by A. L. Rotch (33 pp.). The author in these Nos. gives an account of the services in Germany and Austria, and of the Observatory on the Sonnblick, 10,170 feet above sea-level, which is the highest meteorological station in Europe.—Instruments for making Observations of the Amount and Direction of the Wind, by F. Waldo (17 pp.).—Waterspouts off the Atlantic Coast of the United States (9 pp.).—The meteorological labours of Dove, Redfield and Espy, by M. Bôcher (13 pp.).—The Storm of March 11th-14th, 1888, by W. Upton (18 pp.). The chief characteristics of this storm, which visited the eastern part of the United States, were:—1. the rapidity with which its energy was developed; 2. the excessive precipitation accompanying it, which was principally in the form of snow; and 3. the fact that its maximum intensity was limited to a relatively small area.—The Trans-Mississippi Rainfall problem re-stated, by G. E. Curtis (13 pp.).—Temperature in areas of low and high pressure, by A. Woeikof (4 pp.).

Annuaire de la Société Météorologique de France. Février 1888. 4to.

Contains:—Le brouillard, par E. Renou (3 pp.).—Résumé des observations centralisées par le Service hydrométrique du bassin de la Seine, pendant l'année 1886, par G. Lemoine (28 pp.).—Sur l'application de la photographie à la météorologie, par M. Janssen (3 pp.).

British Rainfall, 1887. On the Distribution of Rain over the British Isles during the year 1887, as observed at more than 2,500 Stations in Great Britain and Ireland, with Articles upon various branches of Rainfall work. Compiled by G. J. Symons, F.R.S. 8vo. 1888. 298 pp. and 4 plates.

In addition to the usual information respecting the year's rainfall, this volume

[1] This paper was published in the *Archives des Sciences physiques et naturelles* for 1886.

contains several articles on rainfall work. As 1887 was a very dry year, the question of droughts is discussed at some length, and Mr. Symons now adopts the following definitions:—1. Absolute Droughts.—Periods of more than 14 consecutive days absolutely without rain. 2. Partial Droughts.—Periods of more than 28 consecutive days, the aggregate rainfall of which does not exceed 0·01 in. per diem. 3. Engineers' Droughts.—Periods of three or more consecutive months, the aggregate rainfall of which does not exceed half the average.

CHARTS SHOWING THE MEAN BAROMETRICAL PRESSURE OVER THE ATLANTIC, INDIAN AND PACIFIC OCEANS. Published by the Authority of the Meteorological Council. Official, No. 76. 1887.

The series of Charts for each Ocean are for the months of February, May, August and November, selected to represent the mean barometrical pressure for winter, spring, summer, and autumn respectively in either hemisphere. Four index charts, on a smaller scale, exhibit the isobars over the entire globe. These are followed by four charts on the same scale showing the range of barometrical pressure.

CIEL ET TERRE. Revue populaire d'Astronomie, de Météorologie, et de Physique du Globe. Deuxième série, 4me année, Nos. 5-10. 1888. 8vo.

The principal meteorological articles are:—L'hiver de 1887-88, par A. Lancaster (9 pp. and 2 plates).—Le "Chinook" (2 pp.).—Les marées atmosphériques (4 pp.).—L'inclinaison du vent (15 pp. and plate).—Les orages, par A. Lancaster (30 pp.).

CYCLONE MEMOIRS. Part I. 8vo. 1888. 48 pp. and 6 plates.

This contains an account of the Balasore Cyclone of May 20th to 26th, 1887, and is the first of a new series. The account of the Balasore Cyclone of May 1887 is the first of a new series of short descriptions of cyclones in the Bay of Bengal which it is intended in future to publish as early as possible after their occurrence. They will be prepared chiefly for the information of sailors and others interested in these storms. Hitherto, in order to make the accounts of the cyclones in the Bay published by the department as complete as possible, they have not been drawn up until all available information had been previously obtained, and therefore have been usually published one or two years after the occurrence of the storms to which they related, and after all ordinary public interest had died away. It is hoped, when the new arrangements for the publication of the present series of cyclone reports have been fully established, they will be issued within two or three months after the occurrence of the storms. The present storm, although a very interesting one in some respects, does not present any such striking and special features as the Calcutta cyclone of 1864, the Backergunj cyclone of 1876, or the False Point cyclone of 1885. It occurred at the change of season, extending from the beginning of May to the middle of June, which ushers in the South-west Monsoon, and during which it is well known, by the experience of some hundreds of years, that violent cyclones occasionally occur. Their formation and motion are now so well understood that the Bengal Meteorological Department in its Daily Report notified its formation on the 20th, or on the same day on which it began, and followed its path, with almost perfect accuracy, day by day, until it reached the coast on the morning of the 26th. There was thus available for the public, for several days before the arrival of the storm on the Orissa coast, much more precise information respecting the position and line of advance of the storm at sea than is ever given by any meteorological bureau in Europe for similar storms in the open sea.

INDIAN METEOROLOGICAL MEMOIRS: being occasional Discussions and Compilations of Meteorological Data relating to India and the Neighbouring Countries. Published under the direction of HENRY F. BLANFORD, F.R.S., Meteorological Reporter. Vol. IV. Part IV. 1887. 4to.

Contains:—List and brief account of the South-west Monsoon Storms generated in the Bay of Bengal during the years 1882 to 1886, by J. Eliot (10 pp. and 7 plates). This list of storms is a continuation of that given in Vol. II. of the *Memoirs*.—The Cyclonic Storms of November and December 1886 in the Bay of

Bengal. by J. Eliot (87 pp. and 7 plates). The retreat of the South-west Monsoon current from Northern India in October 1886 was followed by the occurrence of three cyclones at intervals of about a fortnight. All were generated in the immediate neighbourhood of the Andamans. The first was a large and violent storm, which began to form on November 2nd and 3rd, and moved to the west-north-west. The second cyclone was a very concentrated and violent storm, and was initiated on November 13th. It advanced at first very slowly northward parallel to the Andaman group, and increased rapidly in violence and intensity. The third storm began on December 7th, and was somewhat similar to the first storm, but less severe.

JOURNAL OF THE FRANKLIN INSTITUTE. April 1888. 8vo.

This contains a Lecture (28 pp.) by Mr. E. Hayden on the Pilot Chart of the North Atlantic Ocean, which is issued monthly by the United States Hydrographic Office.

JOURNAL OF THE SOCIETY OF ARTS. Vol. XXXVI. Nos. 1856-1857. June 1888. 8vo.

These contain the "Dr. Mann Lectures" which were delivered by Prof. O. J. Lodge, D.Sc., F.R.S., before the Society of Arts on March 10th and 17th, the subject being Protection of Buildings from Lightning. The following are the concluding paragraphs of the second Lecture:—"In many cases we may be content to fail of absolute security and be satisfied with the probable safeguard of a common galvanised iron rod or rope. But for tall and important buildings, for isolated chimneys and steeples, and for powder magazines, where the very best arrangement is desirable, what is one to recommend? I prefer to call attention to principles rather than to advocate any particular nostrum; but inasmuch as my present opinion is not likely to carry any undue weight, there is no harm in my saying that I see nothing better than a number of lengths of common telegraph wire. I think a number of thin wires far preferable to a single thick one, and their capacity must be increased when possible by connecting up large metallic masses, such as lead roofs and the like. But the connection should be thorough and made at many points, or sparks may result. Balconies and other prominent and accessible places should not be connected. The earth should be deep enough to avoid damage to surface soil, foundations, and gas and water mains. As to the roof I would run barbed wire all round its eaves and ridges so as to expose innumerable points, and the highest parts of the building must be specially protected; but I would run no rods up above the highest point of the building, so as to precipitate flashes which else might not occur, in search for a delusive area of protection which has no existence. The conductors must not be so thin as to be melted or deflagrated by the flash; but really melting is not a very likely occurrence, and even if it does occur, the house is still protected; the discharge is over by the time the wire has deflagrated. The objection to melting is two-fold. First, the red-hot globules of molten metal, which after all are not usually very dangerous out-of-doors; and secondly, the trouble of replacing the wire. I should be content to put up a great number of telegraph wire conductors, and wait till one is melted, before thinking too much of the likelihood of such an occurrence. The few instances ordinarily quoted of damage to lightning conductors by a flash do not turn out very impressive or alarming when analysed."

MEMOIR ON THE WINDS AND MONSOONS OF THE ARABIAN SEA AND NORTH INDIAN OCEAN. By W. L. DALLAS, formerly of the Meteorological Office, London. 4to. 45 pp. and 10 plates. 1887.

This paper is a discussion of Sea Observations collected by the Meteorological Office and supplied by the Meteorological Council to the Indian Government. Monthly Charts are given showing the disposition of atmospheric pressure by isobars, and the mean direction and force of the wind. The mean temperature and vapour tension for the months of April, May and June, are also represented by curves. Lines have been drawn across the Charts of average wind force between the Straits of Babel Mandeb and the North Konkan Coast, giving a rough indication of the axes of greatest and least wind force. These, together with the mean direction of the wind, will be very useful to both sailing ships

and steamers. Larger Charts, including the Indian Ocean down to 20° S., are given for the typical monsoon months, January and July. They represent theoretical views of the South-west and North-east monsoons respectively, which are derived from the best available sources. Conclusions are derived from these data as to the sources from which the monsoons spring, and endeavours are made to account for various peculiarities in their action.

METEOROLOGISCHE ZEITSCHRIFT. Herausgegeben von der oesterreichischen Gesellschaft für Meteorologie und der deutschen meteorologischen Gesellschaft. Redigirt von Dr. J. HANN und Dr. W. KÖPPEN. May-June 1888. 4to.

The principal articles are :—Untersuchungen über unperiodische Temperatur-Aenderungen, von Dr. P. Perlewitz (11 pp.). This is a discussion of 96 years' observations (1791-1886) at Breslau, in order to ascertain the frequency with which changes from day to day of definite amounts occur. At the close of the paper the data for the last 39 years for Breslau and Berlin are compared, and from this it comes out that the former is far more continental than the latter in its climate.—Nord-und Ostföhn in Gries bei Bozen im Januar 1888, von Dr. C. Höffinger (5 pp.). This is an account of a remarkable Föhn felt all along the South Tyrol, at the very time a dense warm fog prevailed over England.—J. Hann: Die Vertheilung des Luftdruckes über Mittel-und Sud-Europa ; besprochen von W. Köppen (14 pp. and plate). This is a review of Dr. Hann's great work on the distribution of pressure over central and southern Europe.—Klimatologische Zeit-und Streitfragen, von A. Woeikof (12 pp.). The author takes four districts, the valley of the Amazons, the central Brahmaputra region (Assam), the north of the Crimea, and a region south of the Alps, Carinthia, Croatia, &c. In all these cases the interior has a lower temperature than the coast, and this Dr. Woeikof attributes mainly to the presence of forests, which by evaporation give rise to clouds. In another paper Dr. Woeikof shows that the alteration of temperature in the daily period is always more rapid than in the yearly period, and that this is strongly marked even in Siberia (Werchojansk and Nukuss) where the annual range is the greatest known, while the contrast is far stronger at tropical stations. One result of this is that the moisture cannot keep pace with the rapid rise of temperature, and so the air is usually driest during the warm hours of the day. In the yearly period the change of temperature is slow, and the moisture can keep pace with it if water surfaces are present to be affected by evaporation. If these are not present streams dry up. Lateral currents bring moisture even to the interior of continents, but not directly, and thus we find Jenisseisk damper than Dorpat, and the upper Amazons than the sea coast. Dr. Woeikof proceeds to show that the fact that water does not exhibit such a range of temperature as dry land is not the greater specific heat of the former, but is to be sought in the following principles : 1. the surface is mixed up by winds and waves ; 2. convective currents ; 3. the diathermancy of water, which allows the sun's rays to reach lower strata ; and 4. evaporation.—Ueber die Vertheilung des Niederschlags im Königreich Ungarn in den Jahren 1871-80, von Prof. V. Raulin (4 pp.).

PROCEEDINGS OF THE ROYAL SOCIETY. Vol. XLIV. No. 268. 1888. 8vo.

Contains :—On the relations of the diurnal barometric maxima to certain critical conditions of temperature, cloud and rainfall, by H. F. Blanford, F.R.S. The author refers to an observation of Lamont's that the diurnal barometric variation appears to be compounded of two distinct elements, viz. a wave of diurnal period, which is very variable in different places, and which appears to depend on the horizontal and vertical movements of the atmosphere and changes in the distribution of its mass, and a semi-diurnal element which is remarkably constant and seems to depend more immediately on the action of the sun. Then, referring to the theory of the semi-diurnal variation, originally put forward by Espy, and subsequently by Davies and Kreil, the author points out that the morning maximum of pressure approximately coincides with the instant when the temperature is rising most rapidly. With respect to the evening maximum of pressure, it is pointed out that very generally, and especially in India, and also at Melbourne, there is a strongly marked minimum in the diurnal variation of cloud between sunset and midnight, which, on an average, as at Allahabad and Mel-

bourne, coincides with the evening maximum of the barometer. A similar coincident minimum, even more strongly marked, characterises the diurnal variation of the rainfall at Calcutta and Batavia in their respective rainy seasons. In the author's opinion these facts seem to point to a compression and dynamic heating of the cloud-forming strata, and he points to the existence of a small irregularity in the diurnal temperature curves of Prague, Calcutta, and Batavia, which may possibly be due to such action. It is further remarked that the evening maximum about coincides with the time when the evening fall of temperature, after a rapid reduction between 6 or 7 and 10 p.m., becomes nearly uniform in rate, and it is suggested that the former may possibly be determined by the check of the rate of collapse of the cooling atmosphere. But it is observed that both the morning and evening waves of pressure probably involve other elements than the forced waves, and are in part rhythmic repetitions of previous waves.

PROCEEDINGS OF THE ROYAL SOCIETY OF EDINBURGH. Vol. XIV. November 1886 to July 1887. 8vo. 562 pp. 1888.

Contains the following meteorological articles :—Temperatures at different heights above ground at Ben Nevis Observatory (4 pp.).—Thermometer screens, by J. Aitken (31 pp. and 3 plates). The author describes a new thermometer screen, and gives the results of some trials made with a Stevenson screen as generally used, and a modified one. He also gives the comparative readings taken with those screens and with the new one.—Note on Solar Radiation, by J. Aitken (3 pp.).—Note on Hoar-frost, by J. Aitken (4 pp.).—The salinity and temperature of the Moray Firth, and the Firths of Inverness, Cromarty and Dornoch, by Dr. H. R. Mill (10 pp. and plate).—Glories, Halos, and Coronæ seen from the Ben Nevis Observatory, by R. T. Omond (13 pp. and plate). This contains extracts from the Observatory log book, and gives the measurements of the various phenomena.—The Thermal Windrose at the Ben Nevis Observatory, by A. Rankine (3 pp.).

REPORT ON THE METEOROLOGY OF INDIA in 1886. By JOHN ELIOT, M.A., Officiating Meteorological Reporter to the Government of India. Twelfth year. 4to. 550 pp. and 5 plates. 1887.

This Report has been prepared on the same plan as in former years. The number of observatories which contributed registers during 1886 was 139. The tables also contain monthly and annual totals of rainfall from 518 stations.

Mr. Eliot gives an interesting summary of the general characteristics and uniformities of the Meteorology of India, which he considers is sufficient to show that there is a direct relation between the pressure anomalies of the year and the local variations of rainfall, and that they do, to some extent at least, give a key to the persistent local irregularities of the rainfall distribution during the South-west Monsoon.

SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. Vol. XXIII. Nos. 268-270. May-July 1888. 8vo.

The principal articles are :—Thunderstorms (5 pp.).—Brazilian Rainfall, 1873-87, by Mrs. Behrens (1 p.).—Hervé Mangon (1 p. with portrait). This is a short obituary notice of the celebrated French meteorologist.—Review of Mr. Velschow's pamphlet on the Natural Law of relation between rainfall and vegetable life and its application to Australia; and the author's reply (6 pp.).—Rainfall of Spain and Portugal (3 pp.).—Waterspouts in the East Riding of Yorkshire (2 pp.).—The Hailstorms of June 25th (3 pp.).

ZEITSCHRIFT DER GESELLSCHAFT FÜR ERDKUNDE ZU BERLIN. Band XXIII. Hefte 2-3. 1888. 8vo.

Contains :—Regenverhältnisse der Iberischen Halbinsel, von Dr. G. Hellmann (96 pp. and plate). This is an interesting and complete discussion of the Rainfall of the Spanish Peninsula, and gives the monthly and annual amounts from 67 stations to the end of 1884.

1 *Stream.*

2. *Ramified.*

3. *Meandering.*

4. *Sinuous.*

REPRODUCTION OF PHOTOGRAPHS OF LIGHTNING FLASHES.

QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY.

VOL. XIV. OCTOBER 1888. No. 68.

REPORT

OF THE

WIND FORCE COMMITTEE

ON

EXPERIMENTS WITH ANEMOMETERS CONDUCTED AT HERSHAM.

DRAWN UP BY G. M. WHIPPLE, B.Sc., F.R.Met.Soc., AND W. H. DINES, B.A., F.R.Met.Soc.

[Read May 16th, 1888.]

THE apparatus most widely adopted by Meteorologists for the measurement of the wind's intensity is the Robinson Anemometer, which, moving with a certain angular velocity about its axis, affords a means of determining the rate of motion of the wind; and, since the wind's force exerted against any obstacle bears a certain ratio to the square of its velocity, it gives also the pressure per square foot, metre, etc. on any plane surface exposed to it.

The most common form of the instrument is that constructed by attaching

four hemispherical cups or shells to the extremities of four bars forming a cross, adjusting them so that the convex surfaces are all placed in the same direction. The centre of the cross is fixed to an upright spindle, which enables it to revolve under the action of the wind in a horizontal plane.

In the *Transactions of the Royal Irish Academy* for 1850, Vol. XXII. p. 168, Dr. Robinson, the Director of the Armagh Observatory, after indicating the attempts at measuring the force of the wind made by Hooke, Dereham, Bouguer, Lind and Osler, showed that their methods of testing it by pressure gauges were unsatisfactory, and stated, "There seem to me sufficient reasons for absolutely rejecting the pressure gauge, and adopting instead of it one which gives directly the velocity, or rather its equivalent, the space traversed in a given time." Such instruments, he stated, had been made by Lomonsoft in 1749 and Edgeworth in 1788.

Woltman invented the hydrometric fly in 1790, and suggested an application of it as an anemometer, which Whewell practically carried out (*Camb. Phil. Soc. Trans.* Vol. VI. p. 301). His instrument was exhibited to the British Association in 1841, and Sir W. Snow Harris proposed to investigate its corrections. These, however, were found to be different for each anemometer, and to vary as the square of the velocity; besides which it was found that the instrument had numerous mechanical defects. The instrument is well known now in the form constructed by Lowne,[1] and is termed the "air meter."

The defects of these instruments led Dr. Robinson to design his well-known anemometer, first described to the British Association in 1846, and subsequently modified, improved and erected at the Armagh Observatory.

After a mathematical inquiry into the theory of his system of hemispherical cups, he writes, "The relation between the velocity of its vanes (cups) and that of the wind can be determined satisfactorily, in the actual state of hydrodynamics, only by experiment."

Dr. Robinson's first experiment led him to the conclusion that the action of the wind on the concave surface of his cups is four times as much as that on the convex, and he states that this very unexpected result so closely agreed with the theoretic value 2·999, that we should be justified in assuming that $\frac{V}{v} = 3{\cdot}000$, where V = the wind's velocity, and v = the velocity of the centre of the cups.

In order to prove this theory experimentally Dr. Robinson constructed a whirling apparatus somewhat similar to that represented in Fig. 1, where four 3-inch cups on (?) inch arms were rotated around a vertical spindle 45·6 inches distant. The whirler was allowed to make usually 96 revolutions, and 35 experiments made at varying speeds gave values of m varying from 3·562 to 3·004. These Dr. Robinson considered as "sufficient to show that after allowing for friction the value of $\frac{V}{v}$ or $m = 3{\cdot}000$," and having made

[1] *Quarterly Journal of the Royal Meteorological Society*, Vol. II. p. 285.

a subsequent experiment with an instrument of different dimensions, he concluded, "that this ratio holds for the larger anemometer as well as the small is shown experimentally."

This dictum of Dr. Robinson's was apparently confirmed by some experiments carried out at the Royal Observatory, Greenwich, by Mr. Glaisher for Sir G. B. Airy, and described in the Introduction to the *Greenwich Observations* for 1862, p. li.

For many years this principle was considered as unassailable as a mathematical axiom, and instruments innumerable have been constructed with cups and arms of all dimensions and bearing ratios of all values.

For accounts of the experiments which have been prosecuted with a view of testing the validity of the Robinson factor, by the Rev. F. W. Stow, M. Dohrandt, Messrs. Jeffery and Whipple, as well as by Dr. Robinson himself, we must refer to papers by Messrs. Stow, Hagemann and R. H. Curtis in the *Quarterly Journal*,[1] and by Dr. Robinson and Prof. Stokes in the publications of the Royal Society, as well as those of Dr. Dohrandt and others in foreign scientific journals.

With the view of further elucidation of the question, we have, on behalf of the Wind Force Committee, made the following experiments during the present year.

The rotating apparatus, termed for brevity the "whirler," already described by one of us to the Committee, has been strengthened and somewhat lengthened and appliances arranged so as to permit of its being driven by the agency of steam.

For this purpose a 8 horse-power horizontal engine and a vertical boiler have been obtained on hire and set up in Mrs. Dines's garden, on the west side of a strong quickset hedge 6 or 7 feet high, whilst the whirler is set up about 40 feet beyond on the opposite side.

A double wire rope, led round a pulley on the main shaft of the engine, passes through the hedge, and thence round a V-grooved pulley on the upright spindle of the whirler, being guided into its place and maintained taut by means of a jockey pulley.

The number of rotations of the whirler is counted by means of a current meter indicator, which also carries an electric contact maker. Wires from the latter run to the vicinity of the engine, and the current causes an electric bell to strike on the completion of every 14¼ revolutions of the whirler, thereby indicating that the end of the latter has passed through half-a-mile of space.

The anemometers tested were four in number, of which three were fixed on the upper surface of the rotating arm, whilst the fourth revolved vertically with its axis in the line of the arm. (Fig. 1.)

[1] The Rev. F. Stow, *Quarterly Journal*, Vol. I. p. 41. M. Dohrandt, *Repertorium für Meteorologie*, Band VI. Mr. Field, *Quarterly Journal*, Vol. V. p. 211. Mr. Curtis, *Quarterly Journal*, Vol. VII. p. 205. Dr. Robinson, *Trans. Roy. Inst. Academy*, 1875; *Proc. Roy. Soc.* Vol. XXX. p. 572; *Phil. Trans.* Vol. CLXIX. p. 777. Prof. Stokes, *Proc. Roy. Soc.* Vol. XXXII. p. 170.

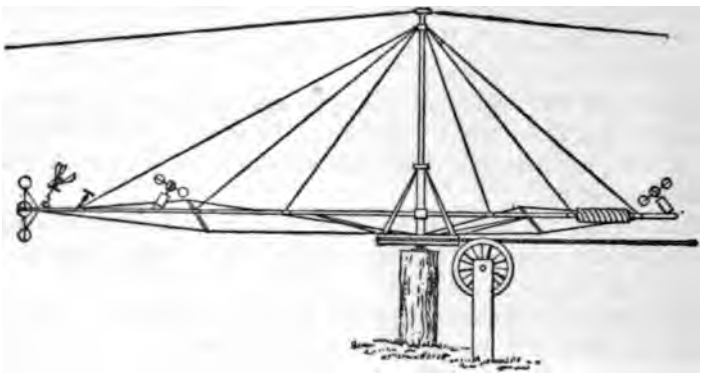

FIG. 1.
Showing the positions of the Anemometers on the Whirler.

They were as follows :—

No. 1.—The Robinson standard. A steel cross with arms 2 ft. lon carrying hemispherical cups of 9 ins. diameter, rigidly stayed by steel wir to a central axis. This is hollow and has bearings 12 ins. apart, construct similar to the ball bearings of a bicycle wheel, and each holding 14 steel spher ⅝ in. in diameter. These revolve so easily that a 40 grain weight placed i one of the cups with its arm horizontal is sufficient to move the instrument. Its revolutions are counted by a train of wheels similar to those of the whirler, and can be recorded as far as 10,000. The centre of the cups is placed at a radial distance of 29 ft. from the axis of the whirler.

Next to the cups a Helicoid anemometer[1] is fixed at a radial distance of 27 ft. (Fig. 2.)

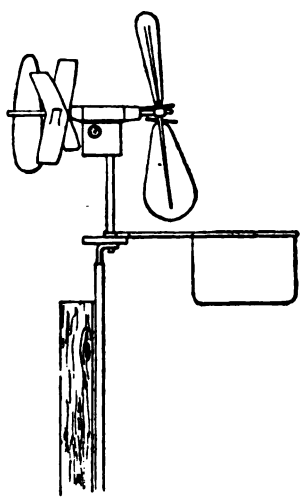

FIG. 2.
Dines's Helicoid Anemometer.

[1] A description of this kind of instrument was read before the Society in April 1887 See *Quarterly Journal*, Vol. XIII. p. 218.

Two of these instruments have been tested. Two small instruments, the property of the Meteorological Office, are Nos. 3 and 4 of the series, and are fixed on opposite arms of the whirler at radial distances of 17 ft. One is numbered A 19, the other A 21.

A 19 has 4 in. cups on arms 5·8 ins. long; and
A 21 „ 2½ „ „ 6·75 „

The construction of both is similar; the last of a train of meter wheels registers every 10 revolutions of the cups, the series running up to 1,000,000 revolutions.

A second Helicoid anemometer is permanently fixed on a post fastened to the fence at a height approximately that of the centre of the whirler and distant 86 ft. from it. Its counter is read at the commencement and conclusion of each experiment, and the difference of the readings is taken as the measure of motion of the atmosphere during the experiment. As most of the experiments have been conducted during calm weather, this motion has scarcely exceeded 4 miles per hour in any experiment, but the corrections to the results which must be deduced from the readings of this instrument have not yet been applied.

Up to the present time some 226 experiments have been made, usually both of us reading and entering in separate books the indications of each instrument; afterwards, reducing them independently at Esher and Kew, we have exchanged comparisons by post.

Each experiment has lasted 15 minutes, the steam pressure remaining pretty constant during the run. The rate of the whirler was also timed very frequently by a chronograph, in order to assist in maintaining a fairly constant velocity, as well as to effect a check on the machine counter.

The whirler has very little momentum, and comes to rest quickly after the steam is cut off. Props are then put up in order to keep all the instruments at rest until their indications are read off and entered. The props are so placed as to fall away and free the cups immediately on starting the whirler on a second experiment.

A few experiments were made with a small Robinson, ¾ in. cups on 2 in. arms, but the results are not submitted herewith.

Table I. gives the result of 69 comparisons of the standard Kew pattern instrument, uncorrected for natural wind. Of these, 6 are rejected as doubtful owing to errors of observation, and 5 are comparisons with a friction brake applied. The remainder give a mean value for Robinson's factor of 2·15.

Table II. exhibits similarly the comparisons of A 19 and A 21.

Of 51 experiments made with A 19, 32 of which were made with the cups in the ordinary position and 19 with them reversed, a mean value of the factor 2·51 is obtained.

Of 49 experiments made with A 21, 32 had the cups in the ordinary position and 17 reversed; the value of the factor determined is 2·96.

Table III. are the results of 25 comparisons of the Helicoid anemometer,

The indications of this instrument vary much less in extent than those of the cup anemometer, the mean factor being 0·996 (1 observation being rejected as obviously wrong), and the extremes 1·024 and 0·935.

TABLE I.—Kew Standard Robinson Anemometer.

Experiment.	Turns of Whirler.	Turns of Robinson.	Factor.	Experiment.	Turns of Whirler.	Turns of Robinson.	Factor.	Experiment.	Turns of Whirler.	Turns of Robinson.	Factor.
1	202	1435	2·04	22	293	2020	2·10	43	155	856	2·62
2	252	1711	2·13	23	193	1309	2·13	44	138	900	2·22
3	290	2086	2·02	24	96	624	2·23	45	159	1058	2·18
4	351	2465	2·04	25	152	1028	2·14	46	225	1518	2·14
5	145	1149	..	26	215	1443	2·16	47	231	1659	2·02
6	152	1074	2·04	27	225	1422	2·29	48	201	1420	2·05
7	269	1803	2·16	28	173	1166	2·15	49	81	542	2·16
8	345	2209	2·26	29	79	601	..	50	182	1254	2·10
9	203	1441	2·04	30	217	1482	2·12	51	193	1333	2·09
10	155	857	2·62	31	253	1747	2·10	52	250	1736	2·08
11	244	1514	2·33	32	297	2044	2·10	53	319	2093	2·21
12	211	1468	2·08	33	179	1239	2·09	54	216	1472	2·13
13	186	1189	2·26	34	148	1017	2·11	55	105	697	2·18
14	175	1498	..	35	111	758	2·12	56	53	248	..
15	180	801	..	36	79	521	2·20	57	52	254	..
16	226	1439	2·29	37	67	402	2·43	58	100	674	2·19
17	266	1796	2·15	38	174	1228	2·05	59	307	2104	2·11
18	168	1184	2·05	39	293	1863	2·28	60	287	1901	2·18
19	210	1446	2·10	40	247	1658	2·16	61	136	968	2·03
20	245	1709	2·07	41	215	1458	2·13	62	271	1840	2·14
21	266	1853	2·08	42	153	968	2·29	63	124	873	2·06
With Friction Brake applied.											
64	224	1554	2·08	66	298	1939	2·22	68	173	692	3·61
65	286	1826	2·27	67	327	1990	2·38	69	199	603	4·77

TABLE II.—Meteorological Office Anemometers (small size), A 19 and A 21.

Experiment.	A 19.		A 21.		Experiment.	A 19.		A 21.		Experiment.	A 19.		A 21.	
	Turns.	Factor.	Turns.	Factor.		Turns.	Factor.	Turns.	Factor.		Turns.	Factor.	Turns.	Factor.
12	314	2·36	242	2·63	29	139	1·99	105	2·27	46	267	2·96	249	2·72
13	281	2·33	209	2·68	30	281	2·72	202	3·29	47	391	2·07	243	2·86
14	248	2·44	177	2·99	31	332	2·66	238	3·19	48	290	2·43	214	3·85
15	220	2·88	173	3·14	32	388	2·68	280	3·20	49	145	1·97	105	2·31
16	301	2·64	214	3·18	33	246	2·54	165	3·09	50	269	2·35	192	2·87
17	337	2·78	251	3·20	34	205	2·54	147	3·05	51	286	2·39	196	2·99
18	245	2·38	182	2·72	35	151	2·57	108	3·11	54	318	2·29	222	2·94
19	289	2·64	207	3·06	36	115	2·39	87	2·71	55	152	2·43	114	2·78
20	338	2·54	248	2·99	37	80	2·94	58	3·48	58	150	2·28	104	2·94
21	356	2·63	266	3·02	38	211	2·90	145	3·55	62	375	2·54	280	2·92
22	387	2·66	282	3·14	39	367	2·81	251	3·51	63	195	2·24	139	2·77
23	265	2·57	193	3·03	40	314	2·70	217	2·43	64	330	2·38	243	2·77
24	138	2·45	100	2·89	41	283	2·69	190	3·41	65	397	2·54	300	2·87
25	212	2·52	153	3·00	42	183	2·94	127	3·63	66	432	2·42	313	2·86
26	283	2·68	203	3·19	43	211	2·59	149	3·13	67	462	2·48	341	2·89
27	290	2·73	203	3·36	44[1]	204	2·38	141	..	68	252	2·41	186	2·79
28	229	2·66	163	3·20	45	214	2·61	148	..	69	258	2·71	192	3·11

[1] Reversed after this.

TABLE III.—Helicoid Anemometer.

1888.	Distance run by Whirler in 15 minutes.	Distance indicated by Helicoid in same time.	Helicoid Percentages of Whirler.	1888.	Distance run by Whirler in 15 minutes.	Distance indicated by Helicoid in same time.	Helicoid Percentages of Whirler.
	Miles.	Miles.			Miles.	Miles.	
March 3 ..	5·24	5·22	99·7	March 24 ..	4·98	5·23	105·0
,, ..	6·75	6·56	97·1	,, ..	4·43	4·36	98·3
,, ..	7·87	7·94	100·9	,, ..	5·11	4·94	96·5
,, ..	8·55	8·76	102·4	,, ..	7·23	7·45	103·0
,, ..	9·41	9·40	100·0	,, ..	7·42	7·42	100·0
,, 12 ..	6·97	6·89	98·6	,, ..	6·46	6·46	100·0
,, ..	8·13	8·25	101·5	,, ..	2·60	2·59	99·6
,, ..	9·54	9·55	100·1	April 7 ..	7·19	7·08	98·3
,, ..	5·75	5·68	98·7	,, ..	9·18	9·18	100·0
,, ..	4·76	4·56	95·7	,, ..	9·57	9·58	100·1
,, ..	3·57	3·34	93·5	,, ..	5·56	5·65	101·6
,, ..	2·54	2·25	..	,, ..	6·40	6·45	100·8

The range of velocity of motion through the air has varied from 5 to 48 miles per hour, but the experiments do not exhibit any very marked relation between changes of factor and velocity for rates from 15 miles per hour to the maximum.

Experiments were made with the axis of the standard placed obliquely to the arm of the whirler, its plane of rotation being inclined at an angle of 37° to the tangent of its path. The effect of the displacement upon the factor was inappreciable.

Experiments to detect the existence of air eddies were made on March 24th. Damp vegetation was burnt under the whirler when in rapid rotation; the observed eddies set up were exceedingly small, none lasting beyond a second or so, and nothing at all approaching a general rotation of the air mass could be detected.

The authors suggest for further experiments more friction experiments and more rotations at high and low, as well as at varying velocities.

DISCUSSION.

Mr. Whipple said that some experiments had been made since the Report was drawn up in order to test the relation between wind pressure and velocity. The Table usually quoted in text books was based on the assumption that the square of the hourly velocity in miles multiplied by ·005 gave the pressure in pounds per square foot. Smeaton was cited in Sir H. James' *Instructions* as the authority for this formula, but on referring to Smeaton's paper in the *Philosophical Transactions* for 1759, it was there found to be stated that these figures were founded upon the results of experiments made at Harborough, in Leicestershire, by Mr. Rouse. The few experiments which had been made with Mr. Dines' apparatus seemed to show that the factor of ·005 was too high, and should be about ·003. This considerably reduced the amount equivalent to given velocities.

The President (Dr. Marcet) remarked that he presumed the wind was always nearly still while these experiments were being carried on.

Mr. Field inquired what was the lowest velocity of the real or artificial wind in miles per hour at which the cups of the anemometers would revolve.

Mr. DINES said he could not say with certainty what was the lowest velocity for which the cups of the anemometer would turn, but he believed it to be between two and three miles per hour.

Mr. MUNRO suggested that further experiments should be made with the whirling apparatus, using pressure plates of different sizes.

Mr. WILSON asked by what means the friction of the anemometers was increased. He supposed that in the early experiments of Mr. Rouse, referred to by Mr. Whipple, a form of anemometer different to the Robinson pattern was used.

Mr. FIELD said he was much pleased with the work which the Wind Force Committee were doing. He took a great interest in anemometry, and nine years ago, at one of the Meetings of the Society, he had pointed out that Dr. Robinson's rule of 3 to 1 was certainly wrong. The Rev. F. W. Stow was, he believed, the first person to draw attention to the discrepancies of anemometrical observations, in a paper read before the Society in January, 1872, where he called into question the accuracy of Dr. Robinson's factor of 3. Dr. Dohrandt next carried out a series of experiments at St. Petersburg in 1874, which clearly showed that Dr. Robinson's factor of 3 was incorrect. Dr. Robinson, however, doubted these St. Petersburg experiments; but Dr. Dohrandt repeated them in 1878, and confirmed the results he had previously made. Dr. Robinson also personally carried out a series of experiments at Dublin in 1878, the results of which also supported Dr. Dohrandt's conclusions, and proved that the assumption that the cups revolved at one-third of the rate at which the wind actually travelled was wrong. Mr. Field then explained a diagram he had prepared on which he had plotted the theoretical results according to Dr. Robinson's assumed factor of 3, and the experimental results at the Crystal Palace in 1872, those obtained by Dr. Dohrandt in 1878, by Dr. Robinson in 1878, and by the Wind Force Committee at Hersham in 1888. The various experimental results were in fair agreement with each other, and clearly showed that Dr. Robinson's rule of 3 to 1 was incorrect. Mr. Field then went on to say, that as far as he knew all instruments, in England at any rate, were constructed on the assumption that the ratio was 3 to 1. For example, when 20 miles had been actually travelled by the cups, the instrument was made to register 60 miles, whereas the Hersham experiments showed the register should have been about 44 miles. He had ventured to say nine years ago that it was wrong to continue the use of the old factor when it was so clearly proved to be incorrect, and he would now press this view of the matter still more strongly. Either the anemometers should be made to record the actual distance run by the cups, or the readings given by the instruments as now constructed should be corrected for the error in the factor. As regarded the experiments carried on at Hersham, he suggested that a considerable number should be made at as low velocities as it was possible to obtain with the apparatus used. The Kew Standard appeared to have an unusually small amount of friction, in fact the experiments, as far as they went, seemed to show that the cups of this anemometer would move for a wind velocity of one mile per hour. The records of the helicoid anemometer were most satisfactory, but he noticed that no results for velocities below 10 miles an hour were given. He had divided the experiments with this anemometer into five groups, according to the velocities, and had marked out the percentages for each group, with the following results ;—

At 16	miles	per	hour	of	the	whirler	the anemometer registered 98·4 per cent.
„ 22	„	„	„	„	„	99·4	„ .
„ 28	„	„	„	„	„	99·4	„
„ 33	„	„	„	„	„	100·9	„
„ 38	„	„	„	„	„	100·4	„

The figures showed the helicoid to be a wonderful instrument. In conclusion, he called attention to the large amount of information which was now available concerning anemometry, and expressed the hope that the Wind Force Committee would work up the investigations that had already been made by different observers. This he considered would be of great service.

Mr. CHATTERTON said that it was the intention of the Wind Force Committee to prepare a digest of all anemometrical investigations, as Mr. Field hoped would

be done. The results embodied in the Report were some of the best that had ever been communicated to the Society, and from an engineering point of view were most valuable. After the Tay Bridge disaster a Board of Trade inquiry was instituted, and evidence as to wind pressure and resistance of structures was given, but practically nothing resulted from the investigation. Engineers had greatly neglected the whole question of wind force and velocity, and it was quite time that this Society took the matter in hand. Great pains had been taken, in connection with the construction of the Forth Bridge, in order to ascertain the probable amount of wind pressure the structure would have to bear, and he was sure Mr. Baker, one of the engineers of this work, would be glad to know that experiments were being made concerning wind pressure. Mr. Baker believed that recorded wind pressures over considerable areas were greatly exaggerated, and he (Mr. Chatterton) agreed with him. Mr. Whipple's remarks on the results as yet obtained certainly supported this belief.

Mr. ABERCROMBY wished to know why the large anemometer at the extremity of the whirler was placed horizontally, and the smaller ones on different parts of the arms obliquely. The object of the experiments was to determine the empirical constants of Robinson's anemometer; but if the empirical position of the instrument standing vertically was not reproduced, the experiments would lose in value. He did not know if the committee were acquainted with the elaborate determinations of the constant of Robinson's anemometer which were constantly being made at the Deutsche Seewarte in Hamburg. The constant obtained there was a good deal larger than that obtained by Mr. Dines, but much less than the old factor of 3. The form of correction mentioned by Mr. Field, constant plus (factor multiplied by the number of revolutions of the instrument), was undoubtedly correct; and was the same as given by Dr. Köppen. He (Mr. Abercromby) did not think that any absolute pressure could be assigned to any given velocity of wind. The pressure on a body exposed to a wind current, of a given velocity, depended on the shape of the body. For instance, a square plate exposed to a wind of 20 miles an hour would experience a certain pressure; if a cone was fitted behind, so as to diminish the eddies, a different pressure would be measured; and if another cone was put in front, so as to make the figure "easy," still another, and probably much less pressure, would be gauged.

Mr. SYMONS said he must say a word in praise of the work done by Mr. Dines and Mr. Whipple. He greatly regretted that more persons had not witnessed the carrying on of the experiments, for he looked upon the results as striking at the fundamental principles of wind measurement. He had himself visited Hersham recently and seen the whirling apparatus, and the ingenuity displayed throughout was simply wonderful. The cost of the whole series of experiments had been under £20, an extremely small sum when the importance of the results obtained was compared with the tens of thousands of pounds spent in the construction and fixing of anemometers, and in the discussion and publication of results now proved to be erroneous. In 1882 the Council of this Society had endeavoured to organise a representative Conference to inquire into the question of wind measurement, but it was understood that the Institution of Civil Engineers intended to institute an inquiry into the matter, and as, with the amount of money at their disposal, it was evident that the Institution was in a better position to successfully carry out such an investigation than our own Society, no further action was taken by us in the matter. Unfortunately, the Institution of Civil Engineers did not proceed with the matter, and the subject remained in abeyance until the appointment of the Society's Wind Force Committee. Regarding wind pressure, when the building for the 1851 Exhibition was being erected, the question of the amount of wind pressure it would have to bear was considered, and it was settled that the probable maximum pressure the structure would be likely to have to resist would be 12 lbs. on the square foot. It was only of late years that pressures of 30 and 40 lbs. on the square foot, and even more, had been recorded. The late Mr. G. Dines had stated that he did not believe there was a church steeple throughout the country which could stand such enormous pressures; and the rough experiments that gentleman made with loaded boxes on the tower of his residence at Hersham supported this belief. These boxes, which should have been blown over at comparatively low wind pressures, sustained pressures, according to anemometric records, many times greater than they were constructed to resist. Having seen the Wind Force Com-

mittee's experiments on the pressure exerted by the wind, he considered them both novel and of high importance.

Mr. C. HARDING said that he had seen the whirler devised by Mr. Dines, and could endorse all that had been said in praise of the apparatus. Unfortunately, the day which he chose for his visit to Hersham turned out extremely wet, and not at all comfortable for the carrying on of experiments. However, Mr. Dines and he did some work, in spite of the bad weather; but he believed the factor deduced from these observations came out larger than in previous experiments. Whether this result was in any way due to the rain, he was not prepared to say. The Report proved that the factor for Robinson's cups was too high. In a previous Report Mr. Chatterton's excellent discussion of the comparison between the estimated wind force at lighthouses and lightships, according to Beaufort's scale, and that registered by anemometers at adjacent observatories, showed the anemometric records to be too high; and Mr. Whipple's statement regarding the equivalents of pressure and velocity indicated that the former were too high, so that these various results all tended to confirm each other.

Capt. TOYNBEE remarked that these results tended to demonstrate the value of Beaufort's scale for the estimations of wind force.

Mr. TRIPP inquired if any reason could be given for the great differences in the factors of the Kew Standard and those of the small anemometers A 19 and A 21, that of the former being 2·15, and of the two latter, one being 2·51 and the other 2·96. Was it in any way due to friction?

Mr. WHIPPLE, in reply, said that the experiments were made on calm days, neither Mr. Dines nor himself caring to go to Hersham on days when they knew it would be useless to expect to obtain any satisfactory or trustworthy results. The actual wind movement during the period of rotation was nearly always observed, as the spare helicoid was mounted in a suitable position near the whirler, and its indications observed. No corrections for wind movement during the experiments had yet been applied. Regarding the pressure plate experiments he would rather not say anything further at present, as they would form the basis of another report at some future time. The friction of the instruments was increased by simply pinching the bearings. He had come to the conclusion that unless the Robinson anemometers could be put into the hands of those who would take care of them, their indications were frequently worse than useless. The instruments required to be continually looked after. Even if carefully attended to and regularly cleaned and well oiled, their records were often far from satisfactory. The anemometer at Kew, which was considered to be a first-rate instrument, had lately frequently stopped when there was a little frost and the wind velocity fell below five miles an hour. He had taken it to pieces and examined and cleaned it repeatedly, but could find nothing wrong with the parts. Respecting the factor of ·005, which was usually given for deducing wind pressure from the velocity, he noticed that in the *Engineer's Pocket Book* for 1854 the factor was given as ·00228, seeming to show that the correctness of the factor commonly given was then doubted. The difference between the factors for the small anemometers A 19 and A 21 was accounted for by the fact that the proportion between the size of cups and length of arms of the two instruments was different, one having small cups on long arms and the other large cups on short arms. The Kew standard anemometer was mounted with its cups in a vertical position in order that they should all be at an equal distance from the axis of the whirler; and the smaller instruments were tilted inwards to overcome the effects of centrifugal force, as it was feared that if the cups were placed perfectly horizontal they might fly off when the apparatus revolved rapidly. He believed the final results of these experiments would prove that the Robinson anemometer as at present constructed and employed was not a reliable instrument.

Mr. DINES said that the thanks of the Society were due to Mr. Munro for making the Kew standard anemometer used in the experiments. He believed the Robinson anemometer would not turn for a velocity of less than two miles per hour. The experiments already made were not yet put into such a form that the factor might be deduced from them with certainty, as no correction for natural wind had been applied. The experiments were mostly conducted on calm days, but it was practically impossible to obtain an absolutely calm day in the open air. The factor usually came out lower when there was a breeze than when the air was calm. He believed the Robinson anemometer required a lower

factor when the wind was gusty than when it was steady. The correction given by the formula of Prof. Stokes, made on the assumption that the cups took up their proper velocity immediately, did not nearly account for the observed discrepancies. He was not prepared at present to say anything about the difference of the wind pressure depending on different shapes and sizes of the plate. The experiments which had been made referred only to a circular plate, quite plain both back and front, and of an area of one quarter of a square foot. On this plate the mean of three experiments made by Mr. Whipple and himself showed that the pressure varied as the square of the velocity, and that a rate of 18·26 miles per hour corresponded to a pressure of 1 lb. per square foot. He, too, thought that wind pressures were greatly exaggerated. In answer to Mr. Abercromby's question, he would say that the anemometers were mounted in the manner shown to obviate as far as possible the danger of the centrifugal force tearing them away from their fastenings.

ON THE INCREASE OF HUMIDITY IN ROOMS

By the Emission of Steam from the so-called Bronchitis Kettle.

By WILLIAM MARCET, M.D., F.R.S., President.

(PLATE IV.)

[Received April 25th—Read May 16th, 1888.]

A GREAT deal has been written about climate, though very little of the climate within doors. To people in good health, young and strong, it does not much matter whether the rooms they inhabit be warm or cold, or damp or dry; but to others in delicate health, whose circulation is probably enfeebled by the accession of years, and mainly for that wide class of the sick who suffer from some bronchial or pulmonary affection, the winter climate in-doors is of paramount importance.

Of course, the temperature of a room must depend first of all on the temperature of the air out of doors. In winter, with snow on the ground and a temperature below freezing-point, we all know how difficult it is to keep up warmth in-doors; in a comfortable house in London the thermometer can hardly be brought up to 57° or 58°, and perhaps 60° in the evening with all the shutters closed.

Much less attention is given to the *humidity* of the air in-doors, for the very reason that we are hardly conscious of any change in this atmospheric condition. We may feel too warm or too cold at home, and "too cold" is the

general complaint in winter, but no one suggests that the air of a room is too dry or too damp, although such meteorological conditions have a distinct influence on health. Man is constantly losing water from his body by evaporation, partly from the skin, but mainly from the lungs. Every breath gives out an amount of moisture not far from sufficient to saturate it. From my own experiments while at the seaside on the Island of Teneriffe, under a mean barometer of 29·92 ins. and at a mean temperature close to 75°, I expired a mean of 4·44 grains of water per minute (mean of 36 experiments); but the whole of this water was not taken from the air passages, as the air inspired held some vapour. This moisture, as estimated by the dry and wet bulb thermometers, showed that the air breathed in one minute contained 1·62 grains of water, which, subtracted from 4·44 grains (the total amount expired), gave 2·82 grains as the actual weight of water given out from the air passages per minute, equal to 169·2 grains evaporated or expired per hour.

The object of this preliminary remark is to give an idea of the amount of heat the body parts with by evaporation from the lungs and air passages. It is stated in Herschel's *Meteorology* that every grain of water evaporated carries off with it sufficient heat to raise 960 grains 1° Fahr., to supply which that quantity of the residual water must have been cooled by 1°. Now, according to this law of nature, 169·2 grains of water evaporated per hour from the bronchial tubes and air passages will carry away a sufficient amount of heat to lower 162,432 grains, say 23 lbs. of water by 1° Fahr., and will therefore rob the blood and body of that amount of heat. Hence it is obvious that the damper the air breathed, the smaller the amount of moisture evaporated from the air passages, and the less cold produced. If the air breathed were saturated at the temperature of the body, there would be no moisture at all given out from the respiratory organs, and consequently no cooling experienced from that cause. Should the air inspired be warmer than the body and comparatively dry, the air breathed will actually come out cooler than it went in. It will now be clearly understood that by adding vapour to the air of a sick room, and thereby increasing its relative humidity, a marked effect is obtained towards reducing the cooling influence of the air breathed on the lungs and air passages,—an important agency towards relieving local congestion of the pulmonary organs.

It is hardly necessary to point out that the relative humidity in-doors is influenced in a great measure by the relative humidity out of doors. On a cold frosty day, with the air nearly saturated out of doors, the air will be very dry in-doors. Thus on January 22nd, 1881, temperature out of doors 27°·5 and relative humidity 90 per cent., the in-door temperature was 49° and relative humidity only 57 per cent., a difference of 33 per cent. On February 1st, 1888, the relative humidity out of doors was 87 per cent. with a temperature of 32°, and the in-door relative humidity was 75 per cent. with a temperature of 57°. Therefore, on cold winter days there are two important conditions to contend against in a sick room, firstly, an accession of cold, and secondly, an excessive degree of dryness.

In 1881 I made a short communication to the *British Medical Journal*, entitled "On the use of Steam in the Sick-room for increasing the Atmospheric Humidity." Finding it difficult to add to the humidity of a room with the ordinary bronchitis kettle, I had one made with vertical tubes carried through and through the boiler in order to increase as much as possible the contact of the flame and heat of a fire with the body of the kettle. The boiler is supplied with a straight tube, funnel-shaped at its opening, and inserted into it through a cork, so that when the water becomes low from evaporation steam is emitted through the tube, and this is a sign that water is required, which is poured in through the funnel.[1]

On looking back lately upon this paper, it occurred to me that the subject might be of interest to the Royal Meteorological Society, and I set to work last Easter to make a few additional experiments on this same subject.

Bronchitis kettles, especially those of the usual kind, though giving out apparently large volumes of steam on a bright fire, increase the humidity of a room less than might be anticipated, and never to the extent of saturation. Thus, in a small room in Grosvenor Street, London, holding only 1,454 cubic feet of air, with an open air temperature of 40° and 96 per cent. of relative humidity, I obtained with the common bronchitis kettle an accession of moisture amounting in one case to from 59 per cent. to 67 per cent. On another occasion the increase was from 61 per cent. to 71 per cent., with a temperature of 41° and relative humidity 88 per cent. in the open air.

In a drawing room holding about 4,184 cubic feet of air, and an adjoining back room about half as large into which it opened, on one occasion I could not obtain any increase of moisture, while on another I succeeded in adding only 5 per cent. to the relative humidity. Another observation was made in a bed room of a capacity of 3,218 cubic feet, the air out of doors containing 83 per cent. of relative humidity, with a temperature of 53°; the steaming was continued in the room from 3.45 to 5.10 p.m., and an increase of relative humidity by only 1 per cent. could be obtained.

In a first experiment with a tubular kettle three pints of cold water were poured into the boiler, which was placed over the fire of the small room previously alluded to, containing 1,454 cubic feet of air. Seven minutes later the water was boiling and steam given out in large quantity. Readings of the dry and wet bulb thermometers were made in the room every five minutes while the steam was given out, the temperature out of doors all the time being 40° and the relative humidity 87 per cent. A maximum increase of relative humidity of 15 per cent. was obtained in the room in thirty-two minutes; the evaporation of water in the boiler had taken place very nearly at the rate of four pints and eight ounces per hour.

Another experiment was made on a cold day in February, the readings out of doors being—temperature 37°, relative humidity 87 per cent. The object was to try the steaming of my bed room, containing 3,218 cubic feet

[1] This bronchitis kettle was made according to my design by Messrs. Probyn & Co., Chemists, Grosvenor Street, W.

of air, with the tubular kettle. The relative humidity in the room before the emission of steam was 58 per cent. Readings of the dry and wet bulb thermometers were made every five minutes. At 12.33 p.m. steam began issuing from the boiler, the maximum degree of humidity reached (at 2.15) was 70 per cent., an increase of 12 per cent. on the humidity in the room before steaming was commenced.

The last four experiments were made recently in a house in Wimbledon Park; the room selected for the purpose was carefully measured, and found to have a capacity of 2,829 cubic feet. The results of these observations are given in the form of four diagrams, the lines of the abscissæ corresponding to the different degrees of relative humidity and those of the ordinates to the time of observation.

Experiment I. In the open air at 5.20 p.m., dry bulb 37°·8, wet bulb 37°·2, raining. A glance at the diagram of this experiment shows that five minutes after steam began pouring into the room the relative humidity had risen from 58·8 per cent. to 66 per cent., the rise was then more gradual until it reached its maximum of 69·5 per cent. in thirty-five minutes after the experiment was commenced. The humidity remained stationary for a quarter of an hour, when the evolution of steam being stopped the humidity at once began to fall.

Experiment II. Before steaming, the relative humidity, out of doors, under a screen, amounted to 78 per cent., and in the room to 65 per cent. Four pints of cold water were poured into the boiler, and at 12.30 p.m. placed on a fire, not bright at the time. At 12.44 steam was emitted, and at 12.45 came out abundantly. As seen in the diagram, a rapid increase of relative humidity took place in the room. At 1 p.m., or after a quarter of an hour, the humidity had risen from 65 per cent. (before the experiment) to 71 per cent., or by 6 per cent. The increase of humidity continued with fair steadiness until 1.35, when it attained its maximum of 80°·5 per cent. No water was added in the kettle, and the experiment went on uninterruptedly. At 1.10, or when the humidity had increased from 65 per cent. (at the beginning) to 74 per cent., the windows of the room began to show a deposit of moisture. After stopping the emission of steam the fall of humidity was rapid, and in thirty-five minutes it had nearly reached its initial state before the experiment.

Experiment III. was begun at 12.45 p.m., and continued till 3.50 without interruption. Out of doors, in a Stevenson screen, at 12.38, the dry bulb temperature was 45°·0, the wet bulb 42°·0, and the relative humidity 78. The same speedy rise of humidity observed in the preceding experiment is again noticeable. The maximum relative humidity of 80·5 was obtained at 1.50, say an hour after steaming had been commenced, amounting to an increase of 17 per cent. on the initial proportion. The humidity then fell rapidly to 74·5 per cent., as the issue of steam ceased for seven minutes, cold water having to be added. Vapour again issued from the kettle at 1.57, but the steam failed to raise the moisture to its maximum height, and the relative humidity of the room remained between 73·5 per

cent. and 76·5 per cent. until the kettle was taken off the fire at 8 p.m. The humidity at once fell rapidly and reached 68 per cent. at 8.30 (having fallen from 76·5 per cent.), when, from some unexpected cause, it again rose from 68 per cent. to 71 per cent. in the course of a quarter of an hour, the experiment being then concluded. On this occasion four pints of cold water had been poured into the empty kettle at 12.35, when the experiment was begun, and at 12.48, or thirteen minutes later, the water was boiling and steam given out in large volumes. The amount of water evaporated into the room amounted to six pints and seven ounces in two hours and twelve minutes, being at the rate of one pint in twenty-one minutes, say very nearly one ounce per minute. In this experiment I tried whether, by changing the position of the dry and wet bulb thermometers in the room and placing them close to the ceiling, the readings would be in any way affected, always taking care to avoid direct radiation from the fire, but I could find no marked influence from such changes.

Experiment IV. shows the highest absolute degree of moisture obtained from all my experiments. The relative humidity rose in one hour and twenty minutes from 68 before steaming the room to 85·0 or by 17 per cent., as in the previous experiment. The fire under the boiler was carefully attended to, and hot water was used to make up for the evaporation, so as to avoid any intermission in the evolution of the steam; even then there was no steam for one or two minutes, when the diagram shows an immediate fall of humidity at 5.40 from 88·6 per cent. to 80 per cent. A circumstance which greatly contributed to this high state of moisture within doors was the extreme humidity of the external air, as rain was falling the whole time the experiment lasted; the air was not, however, quite saturated, the thermometers in the Stevenson screen reading, dry bulb 46°·8, wet bulb 45°·0, corresponding to 87·4 per cent. of relative humidity.

Steaming a room with a kettle, care being taken that all the steam be let into the room through a long spout, *and none lost in the direct draught of the fire*, appears to me to afford a ready and tolerably correct means of estimating the ventilation of that room. In this case the room experimented in had a capacity of 2,829 cubic feet, and I shall take Experiment IV. as illustrating the present method for estimating its rate of ventilation. Four pints and fourteen ounces, amounting to 41,125 grains of water, were evaporated from the boiler in one hour and twenty-five minutes, and when the emission of steam was stopped after that lapse of time the room held 14,824 grains of vapour as calculated from Glaisher's tables. But some of this vapour was derived from the external air, and we may consider its amount the same as it was just before the steaming was commenced, assuming the relative humidity in the open air remained constant during the experiment, which was obviously the case as it rained the whole time. Now the weight of the vapour in the room before the steam was given out amounted to 11,288 grains, which weight, subtracted from the total moisture in the room after the steaming was stopped, yields 3,536 grains of vapour in the room from the boiler only. The

relation between the total amount of vapour given out from the kettle and the vapour left in the room (from the kettle only) shows the number of times the air has been renewed in the room, as the air and vapour go out and come in together, and 41,125 divided by 3,536 equals 11·6 for the rate of frequency of the renewal of the air in the room during 1 hour 25 minutes, or 85 minutes. Dividing 85 by 11·6 gives 7·33, and therefore the air in the room was renewed entirely every 7·33 minutes. The capacity of the room, 2,829 cubic feet, divided by 7·33, will show that 386 cubic feet of air went in and out of the room every minute throughout the experiment, which corresponds to its speed of ventilation.

A similar mode of reasoning applied to experiment No. III. shows a speed of ventilation of 389 cubic feet per minute. This result only differs from the former by 3 cubic feet, say less than one per cent.; the various conditions of experiment No. III. were widely different from those of experiment No. IV., although the out-of-doors temperature was somewhat nearly alike; this appears to me as showing the accuracy of the present method.

The estimation of the ventilation of a room by the present means would, therefore, require the following data:—1. The relative humidity of the room before steaming. 2. The relative humidity of the room ascertained a certain time, say three quarters of an hour or an hour after steaming has begun, and when found tolerably constant. 3. The weight of the water reduced into vapour during the time the steaming has been carried on.

The weight of the vapour contained in the room when steaming is stopped, reduced by the weight of the vapour originally present in the room, gives the actual weight of vapour in the room supplied by the steam emitted; and the weight of the water evaporated compared with or divided by the weight of the vapour present in the room from the steam emitted will yield the number of times the air is changed during the period of steaming. Knowing the capacity of the room, it is easy to find out how many cubic feet per minute come in and go out of it. I am prepared to hear objections to this method, the principal one being perhaps the deposit of moisture on the cold surfaces of the room. This, I think, cannot hold good, except with reference to the windows, as the air in the room is never saturated, and cannot lead to any great error. My present object is mainly to suggest the method as one which I think fairly correct, while practical and easy in its application.

The present inquiry shows that the temperature of a room is not much altered, though in general somewhat increased, by letting out steam into it from a kettle on the fire. In the first experiment the initial temperature of the room was 60° at 4.20 p.m., and was also 60° when the steaming was stopped at 5.5. In the second experiment initial temperature was 57° at 12.45 p.m., and temperature on taking off steam at 1.35 was 59°·3, a rise of 2°·3. In the third experiment the initial temperature was 58° at 12.50 p.m., and on taking off steam at 3 p.m. it was 61°, a rise of 3°. In the fourth experiment the initial temperature was 60°·6 at 5 p.m., and 62°·2 at 6.30, a rise of 1°·6.

DISCUSSION.

Dr. WILLIAMS said that he considered Dr. Marcet's kettle was a great improvement on the ordinary form of bronchitis kettle. He frequently advised its use, and had found that it was not always necessary to place it on the fire as directed, as the water would boil up very quickly if it merely stood in front of the fire. In cases of bronchitis it was invariably a good thing to steam the room; but the use of steam, while it had many advantages, had one drawback, as it frequently caused the patient to perspire too freely, and while this might be good in some cases, it would be harmful in others. He welcomed Dr. Marcet's paper as leading the way to a better study of indoor climate, for he felt that we ought to give as much attention to the condition of the atmosphere of our rooms as we do to the conditions and changes of the outside atmosphere. He had been told that the climate of Madeira was very similar to the artificial climate produced in a room by the emission of large quantities of steam into it. He could not quite understand how Dr. Marcet proposed to use the process of steaming as a means of determining the rate of ventilation in a room, and he was not quite sure that in his calculations he had not omitted the vapour emitted by his own body, also the condensation of vapour on the windows and walls, as well as that escaping up the chimney.

Mr. LATHAM inquired how many instruments were used in these experiments. He had made some hygrometrical observations in a cellar, and he found that the dry and wet bulb thermometers were immediately influenced by the presence of the observer when making an observation, and required to be read quickly. He hoped Dr. Marcet would print vapour tension figures when the paper was published in the Journal, as the relative humidity conveyed no idea of the actual amount of moisture which the air contained. It was possible for the steam to raise the temperature of the room and yet not increase the amount of relative humidity. He could not believe that any accurate measurement of the ventilation of a room could be attained by the method suggested in the paper, as a large quantity of steam would be lost in the draught up the chimney, and it could not be certainly known whether the steam was evenly diffused into the air of the room.

Mr. TRIPP asked if any inconvenience was experienced from the condensation of moisture consequent on steaming the room.

Dr. BUCHANAN said that people who, like himself, had to deal with sanitary problems were very much in want of a ready and direct method of ascertaining the total amount of air which passed through a given closed space during a given period. Dr. Marcet's paper appeared to indicate that such a method might be forthcoming, and he hoped Dr. Marcet would continue his researches with a view to completely fulfilling the object of giving to sanitarians the means of measurement that they wanted.

Mr. SYMONS suggested that if a paraffin lamp, such as was used in the paraffin cooking stoves now so common, were employed for the purpose of heating the water in the kettle, it would diminish the loss of steam up the chimney, and could be placed in any part of the room. The most suitable instrument for use in the wards of a hospital, in order to determine readily the humidity of the air, was either Saussure's Hair Hygrometer or Lowe's Hygrometer, both of which instruments gave the amount of moisture direct, without the trouble of calculation. He suggested that Mr. Latham would get rid of the personal error in the observations of his dry and wet bulb thermometers if he used one of Negretti and Zambra's turn-over dry and wet, which would record the temperatures at any time for which they were set, without the observer entering the room.

Mr. BUCHAN said that the subject of the connection between moisture and disease had been in his mind for many years past. About thirty years ago he lost his voice, and was a long time before he recovered it. He was obliged to wear a respirator during this time night and day, but he believed he would have recovered sooner if it had been possible to get more moisture in the room which he inhabited. Sir Arthur Mitchell and he had carried out an elaborate investigation concerning the relation between mortality and disease, and the weather at the various seasons of the year. They found, among many other conclusions, that there was a maximum fatality in spring from all brain diseases, and that whoop-

ing cough was most fatal in the spring months, while scarlet fever was at its minimum in the spring time.

Dr. BARNES said that he had drawn up tables showing the relation of fevers to meteorological conditions on the basis of tables constructed by Mr. Buchan. It was remarkable how these agreed. The two sets of curves, Buchan's for thirty years and his own for ten years, showed that fevers prevailed in cold weather, and became much less frequent in summer. This pointed to a practical lesson to study the means of assimilating "domestic meteorology" to the healthy natural meteorology of summer. He looked upon Dr. Marcet's paper as a most important contribution in this direction.

THE PRESIDENT (Dr. Marcet), in reply, said that this paper was a very short contribution to the subject, and he hoped that more would be done. He entirely agreed with Mr. Latham's remarks as to the greater utility of vapour tension values over percentages of relative humidity, but he had chosen to express the results in relative humidity, because this was simpler and easier to understand for persons unacquainted with the meaning of the term tension of vapour. Then, too, relative humidity values, while they did not express the actual amount of moisture in the air, served to convey an idea of its relative condition. Mr. Buchan's remarks concerning the relation between the seasons and the prevalence of diseases were of the greatest importance.

THE COLD PERIOD FROM SEPTEMBER 1887 TO MAY 1888.

By CHARLES HARDING, F.R.Met.Soc.

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THE whole of the winter of 1887-8, as well as a large part of the autumn and spring, may be characterised as having been most persistently cold. The principal feature, however, which rendered the mean temperature for the several weeks so abnormally low, was not the occurrence of exceptionally low minima, for in this respect the cold spell has been considerably outstripped in several recent winters, although some decidedly low minima occurred, especially in the autumn of 1887. The cold period through which we have just passed was due principally to the unusually low day temperatures, that is, rather to the absence of high than to the prevalence of low temperatures.

The following is a brief history of the weather for the several months September 1887 to May 1888.

SEPTEMBER was characterised by very changeable weather. The month opened with stormy unsettled conditions, but the latter part was generally fine and dry. Temperature was below the average over the whole of the United Kingdom, to the extent of from 1° to 8°, except in the east of Scotland, where average conditions were experienced.

OCTOBER was very cold, the type of weather during the greater part of

the month was anticyclonic, and consequently but little rain fell. The deficiency of temperature ranged from 5°, over the greater part of England, to between 2° and 4° in Scotland and Ireland. In London the mean temperature for the month was 5°·8 below the average. Towards the close of the month very low temperatures were recorded in nearly all parts of the Kingdom, and at Greenwich the thermometer registered lower readings on two separate occasions than in any previous October during the last half century. The mean for the month was lower than in any previous year during the last 50 years, but in 1840-1 and 1842-3 the temperature was only 0°·1 higher.

NOVEMBER opened with exceptionally stormy weather, no fewer than five distinct disturbances arriving within the area of the British Islands during one week; the remainder of the month, however, was fairly quiet. Some sudden changes of temperature were experienced, and there was frequent occurrence of fog. The temperature for the month was in defect of the average except in the north-east districts, but the general deficiency over the whole country only amounted to 1°·5.

DECEMBER was fairly warm at the commencement, but cold and frosty towards the close. The mean temperature for the month was generally in defect of the average, but the difference over the British Islands was nowhere large. The air during the month was excessively damp, although the rainfall measured was considerably below the average quantity.

JANUARY was marked by spells of cold as well as spells of mild weather; the British Islands, however, escaped much of the rigour of winter to which Europe generally was subjected. The temperature for the month was below the average in England, in agreement with average conditions in Ireland, and slightly above the mean in Scotland. At Durham a shade temperature of 68° was registered on the 9th, which is a reading by no means common even in the early spring months, and was not again recorded until after the close of April in any part of this district. The rainfall for the month was very largely in defect of the average.

FEBRUARY was cold and dull throughout, with frequent and heavy falls of snow. Unusually low temperatures were recorded both at the commencement and towards the close of the month. From February 15th to March 1st the maximum temperature at Greenwich did not exceed 40°, and on three consecutive days, February 22nd to 24th, the highest day temperature did not reach the freezing-point, whilst on the 24th the thermometer did not rise above 29°·7. From February 16th to March 6th, for 20 consecutive nights, the thermometer in the shade was below 32°. The only previous instances of frost for 20 or more consecutive days at Greenwich from 1845 are: 28 days in 1886, from February 19th to March 18th; 24 days in 1858, from February 17th to March 12th; 22 days in 1879, from November 20th to December 11th; 21 days in 1855, from January 14th to February 3rd; and 21 days in 1878, from December 6th to 26th. The mean temperatures for the month show a deficiency ranging from 8° in the northern and western parts of the Kingdom to 6° in the south of England and 7° in the south-west of England. In no district did any individual temperature exceed 54°.

MARCH was a very cold month, but the precipitation, which included a fair quantity of snow, was considerably larger than of late, and was in excess of the average in all parts of the United Kingdom. The mean temperature ranged from 4° to 6° below the average, and, as in February, the greatest deficiency was during the day hours. During the whole period 60° was reached only in the Midland Counties and in the south of England.

APRIL was cold, the deficiency of temperature over the United Kingdom ranging from 3° to 5°. In the western, or principal grazing, districts the day temperatures did not exceed 62° throughout the period, and the absolute highest reading anywhere in the British Islands was only 66°. In London the mean temperature was 5°·5 below the average, and a lower mean has only occurred three times during the last half century. The rainfall during the month was generally in fair agreement with the average.

MAY was cold in the early part of the month, but somewhat warmer in the latter part; the mean for the whole period, however, was slightly in deficit in all the English districts and in Ireland, whilst in Scotland it was in agreement with the average conditions. The weather was very dry over England, and in many places there were long periods without any rain falling. The total fall over the whole of the United Kingdom was only about one half of that which fell in April. In London rain only fell on 4 days during the month, and the total measurement was 0·80 in., which is considerably less than one half of the average quantity.

The bulk of the data employed in the formation of the following Tables is taken from the published works of the Meteorological Office, and chiefly from the *Weekly Weather Report* and its Appendices.

Table I. shows how largely the deficiency of temperature prevailed over the excess, and this relation was common to all districts in the British Islands. In the north-west of England there were but three weeks during the whole period of 36 weeks, from September 6th, 1887, to May 14th, 1888, in which the mean temperature was above the average, and in each of the districts, Scotland, N., England, E., Midland Counties, England, S.W., and the Channel Islands, the mean was above the average only in five weeks. The districts in which the excess of temperature was most frequent were Scotland, E., 12 weeks; and Scotland, W., and England, N.E., 7 weeks. There were only three weeks in which an excess of temperature was common over the whole country, these were the weeks ending December 5th, January 9th, and March 12th.

The deficiency of temperature was very large in the three weeks ending February 20th, 27th and March 5th, the difference from the average amounting to as much as 10° in some parts of the United Kingdom during each week. There has been no similar period of three consecutive weeks with so large a defect of temperature during the last ten years, and there have been but four instances of two consecutive weeks, occurring respectively in December 1878, December 1879, December 1882, and March 1886.

The mean defect of temperature over the whole of the British Islands, and for the whole period, amounted to about 8°.

TABLE I.

DIFFERENCE OF MEAN TEMPERATURE FOR EACH WEEK FROM THE AVERAGE OF 20 YEARS, 1861–1880.

Week ending	Scotland, North.	Scotland, East.	England, North-East.	England, East.	Midland Counties.	England, South.	Scotland, West.	England, North-West.	England, South-West.	Ireland, North.	Ireland, South.	Channel Islands.
1887.	°	°	°	°	°	°	°	°	°	°	°	°
Sept. 12	−4	−2	−3	− 3	− 3	− 3	−3	−3	− 2	−3	− 2	− 1
19	−2	−2	−4	− 4	− 4	− 3	−3	−4	− 3	−2	− 2	− 2
26	0	+1	−2	− 3	− 3	− 3	0	−1	− 2	−1	− 2	− 1
Oct. 3	−1	−1	−3	− 5	− 5	− 5	−2	−3	− 5	−2	− 4	− 4
10	−3	−2	−3	− 2	− 3	− 2	−3	−3	− 3	−2	− 3	− 3
17	−6	−5	−7	−10	− 9	−10	−7	−8	− 9	−5	− 7	− 7
24	−2	−1	−3	− 6	− 5	− 6	−1	−3	− 4	−1	− 2	− 4
31	−1	0	−2	− 4	− 3	− 4	−1	−3	− 4	−2	− 2	− 4
Nov. 7	+1	+2	0	0	+ 1	+ 1	+2	0	− 1	0	0	− 1
14	−2	−1	+1	0	0	0	0	−1	− 2	−1	− 2	− 2
21	−1	−2	−5	− 9	− 8	− 8	−3	−8	− 7	−4	− 6	− 5
28	−1	+1	+1	+ 1	+ 1	+ 1	0	0	− 1	−1	− 1	0
Dec. 5	+2	+4	+2	+ 2	+ 2	+ 2	+3	+1	+ 1	+2	+ 1	0
12	−7	−4	−4	− 3	− 1	0	−3	−3	+ 1	−3	− 1	+ 1
19	−3	0	0	+ 6	+ 1	+ 2	0	0	+ 2	−1	+ 1	+ 2
26	−5	−3	−4	− 6	− 5	− 6	−5	−5	− 6	−2	− 5	− 4
1888.												
Jan. 2	−4	−4	−4	− 6	− 6	− 8	−4	−6	− 7	−5	− 6	− 6
9	+6	+8	+5	+ 4	+ 5	+ 4	+6	+4	+ 3	+5	+ 5	+ 3
16	+2	+2	0	− 2	− 5	− 5	+2	−2	− 5	+1	0	− 3
23	−1	+1	0	0	0	− 1	+1	−2	0	0	+ 2	0
30	−3	+1	−1	− 2	− 2	− 2	−1	−1	− 4	−1	− 1	− 3
Feb. 6	+1	+3	+1	− 3	− 1	− 3	+3	0	− 3	+2	0	− 2
13	−5	−1	−1	0	0	0	−2	−2	− 1	−2	− 2	+ 1
20	−9	−7	−6	− 7	− 8	− 9	−8	− 8	−10	−5	− 7	− 7
27	−4	−5	−6	−11	−10	−12	−6	−8	−12	−6	− 8	−10
Mar. 5	−4	−4	−5	− 8	− 8	−10	−4	−6	− 9	−4	− 6	− 8
12	0	+2	+3	+ 3	+ 3	+ 1	+2	+1	+ 1	+2	+ 2	+ 2
19	−7	−9	− 8	− 8	− 7	− 7	−8	−9	− 7	−7	− 6	− 5
26	−5	−5	−5	− 6	− 5	− 7	−5	−6	− 7	−4	−11	− 6
April 2	−5	−5	−5	− 4	− 4	− 4	−5	−5	− 5	−6	− 6	− 3
9	−4	−5	−7	− 9	− 9	− 9	−5	−8	− 7	+5	+ 6	− 8
16	−1	+1	0	− 2	− 1	− 3	0	−1	− 2	+1	+ 2	− 2
23	−3	−3	−3	− 4	− 3	− 4	−3	−3	− 4	−4	− 3	− 2
30	−3	−2	−3	− 5	− 4	− 4	−3	−5	− 5	−4	− 3	− 4
May 7	−1	+1	+1	− 2	− 1	− 3	−1	−2	− 3	−2	− 2	− 2
14	−4	−1	−3	− 4	− 3	− 2	−2	−4	− 2	−4	− 2	− 2

Table II. shows a very marked absence of high temperatures. In the North-west of England 60° was not exceeded from September 27th to April 30th,—a period of 31 weeks,—and in the Channel Islands it was only once exceeded in a similar period, whilst in several other districts long periods are shown without a single high temperature. An examination of the *Weekly Weather Reports* for the corresponding period during the last ten years shows that 60° is nearly always exceeded in all districts during October and April, and very frequently also in November and March.

Table III. shows to what extent the period under consideration is remarkable for the absence of high day temperatures.

TABLE II.

HIGHEST TEMPERATURE OBSERVED IN EACH WEEK.

Week ending	Scotland, North.	Scotland, East.	England, North-East.	England, East.	Midland Counties.	England, South.	Scotland, West.	England, North-West.	England, South-West.	Ireland, North.	Ireland, South.	Channel Islands.
1887.	°	°	°	°	°	°	°	°	°	°	°	°
Sept. 12	61	66	67	69	69	69	63	64	67	64	74	69
19	61	68	64	66	66	66	62	63	67	64	69	68
26	62	68	64	65	68	70	69	64	71	67	66	65
Oct. 3	61	66	60	61	62	62	63	60	61	63	63	61
10	58	65	59	60	61	65	60	60	61	60	62	58
17	56	61	57	57	59	59	58	55	64	54	59	58
24	58	57	56	56	60	59	54	55	61	58	60	61
31	55	60	56	61	61	61	58	54	59	57	60	59
Nov. 7	50	54	53	56	56	56	53	52	55	54	58	55
14	52	49	50	51	52	53	51	52	53	53	53	57
21	50	51	46	46	45	47	50	46	48	48	50	49
28	52	55	53	54	53	54	53	54	53	52	55	54
Dec. 5	54	55	54	53	55	52	53	54	54	52	55	53
12	46	46	52	55	59	54	52	52	55	53	58	54
19	50	50	51	54	52	53	53	55	53	51	54	53
26	45	49	42	43	43	45	46	46	49	47	49	48
1888.												
Jan. 2	42	47	42	45	44	47	47	48	48	45	49	47
9	54	57	63	59	59	53	55	57	55	59	59	53
16	54	54	53	57	52	52	52	50	47	56	52	48
23	51	53	52	52	55	53	52	51	55	56	58	51
30	51	52	51	49	53	50	52	51	48	54	56	49
Feb. 6	51	54	53	51	54	54	54	51	52	53	53	50
13	48	52	54	53	52	53	47	48	53	50	51	50
20	41	45	41	43	42	45	44	43	44	49	49	46
27	46	42	40	37	41	40	42	41	41	48	44	41
Mar. 5	48	49	45	45	48	48	47	45	49	52	53	47
12	53	56	58	57	61	61	53	56	56	57	59	54
19	51	47	42	53	50	52	47	43	52	50	53	53
26	48	53	50	49	54	49	51	54	54	54	54	51
April 2	50	53	50	56	57	54	50	51	52	53	54	52
9	51	58	50	49	53	49	52	49	54	54	53	46
16	57	62	62	66	63	63	60	59	59	61	62	59
23	58	57	60	62	61	59	56	57	58	58	58	56
30	55	61	60	66	66	65	55	60	61	59	58	60
May 7	62	70	69	72	72	69	60	66	65	66	69	60
14	57	68	68	68	71	73	62	63	69	61	66	66

Tables IV. and V. show very clearly the very exceptional character of the cold spell of weather experienced from September 1887 to May 1888. The unit employed in these Tables is the number of day-degrees above or below 42°, that is, the accumulated excess or defect from a base temperature of 42° Fahrenheit in a day of 24 hours. This method of registration is probably the best employed as a record of effective or non-effective heat necessary to the progress of vegetation, but in this case the accumulated temperatures hav been thrown together for the period of 36 weeks, to show the departure abo and below 42°, and the values afford a comparison of the persistency of co The base of 42° is chosen as that above which vegetation is active, and be which it is at a standstill or inactive, and some horticulturists have advar the opinion that if the night temperature falls to 42° vegetation will sho

TABLE III.

INSTANCES IN WHICH HIGH TEMPERATURES HAVE BEEN RECORDED DURING THE PERIOD OF 36 WEEKS, FROM THE COMMENCEMENT OF SEPTEMBER TO THE MIDDLE OF MAY IN EACH OF THE TEN YEARS, 1878–1888.

Years.	Number of Weeks with Temperature 70° or above.											
	Scotland, North.	Scotland, East.	England, North-East.	England, East.	Midland Counties.	England, South.	Scotland, West.	England, North-West.	England, South-West.	Ireland, North.	Ireland, South.	Channel Islands.
1878–79	..	2	3	5	5	3	3	2	3	1	2	..
1879–80	..	..	1	2	1	3	1	..	2	..	1	..
1880–81	..	1	4	4	4	5	..	..	1	..	1	..
1881–82	..	..	1	1	5	4	..	..	1	..	..	..
1882–83	..	1	1	3	3	2	1	1	..	..	..	..
1883–84	..	3	4	4	5	4	2	3	4	1	..	..
1884–85	1	2	2	4	5	4	2	2	3	3	2	1
1885–86	..	1	3	5	7	6	..	2	4	2	2	3
1886–87	..	2	2	5	5	7	..	3	4	..	1	3
1887–88	..	1	..	1	2	2	..	..	1	..	1	..
	No. of Weeks with Temperature 60° or above.											
1878–79	..	9	10	14	14	15	8	8	11	8	10	..
1879–80	..	11	13	15	16	17	10	8	15	9	14	..
1880–81	..	8	12	13	16	14	8	9	10	9	9	..
1881–82	..	9	12	14	17	17	8	12	16	13	15	..
1882–83	..	10	11	15	16	15	8	12	14	12	12	..
1883–84	..	10	11	14	12	14	12	11	14	9	15	..
1884–85	4	11	10	13	13	16	7	11	13	11	10	10
1885–86	4	11	10	13	14	13	7	11	13	11	11	9
1886–87	8	14	12	13	14	16	11	12	15	12	12	9
1887–88	5	11	10	11	12	11	8	8	10	8	10	8

growth during the next 24 hours. Whether the latter is a fact or not, the figures for 1887-88 are quite sufficient to show why vegetation is in a very backward condition. The day-degrees above 42° in 1887-88 were very decidedly below those for the corresponding period in all districts during the previous nine years, and in some years when the winters have been mild the difference is excessive. The day-degrees below 42°, giving essentially a measure of low temperatures, or non-effective heat, show that in the South-west of England and in the Channel Islands the cold was more intense in 1887-88 than in any previous year, and in the other districts the cold was greater than in former years with the exception of 1878-79 and 1880-81. Table V. shows the period for 1887-88 to be coldest, and it is the only year of the ten thus dealt with that the mean departure for the whole of the British Islands has a negative or non-effective value. It is, however, not very different in result from the corresponding period for 1878-79, but in the latter case the balance is in favour of effective heat. Of all recent years 1881-82 was the most favourable to vegetation, and the next in order was the year

TABLE IV.

Accumulated Heat in 36 Weeks, from the commencement of September to the middle of May in each of the Ten Years, 1878–1888.

Years.	Day-Degrees above 42° Fahrenheit.											
	Scotland, North.	Scotland, East.	England, North East.	England, East.	Midland Counties.	England, South.	Scotland, West.	England, North-West.	England, South-West.	Ireland, North.	Ireland, South.	Channel Islands.
1878–79	663	779	846	978	986	1083	928	900	1297	954	1223	1495
1879–80	762	940	964	1111	1134	1240	1036	1058	1455	1125	1359	1447
1880–81	588	808	871	1076	1091	1293	870	970	1440	1003	1338	1676
1881–82	874	1096	1122	1312	1335	1518	1157	1222	1612	1246	1621	1931
1882–83	715	859	912	1090	1103	1332	1001	1050	1327	1032	1252	1595
1883–84	747	981	1063	1305	1285	1464	1084	1196	1479	1213	1538	1815
1884–85	742	964	1050	1254	1218	1439	1036	1126	1398	1159	1375	1505
1885–86	589	797	808	996	1009	1165	776	899	1143	938	1160	1500
1886–87	804	998	1018	1183	1143	1360	1039	1033	1340	1130	1382	1636
1887–88	501	658	641	815	794	911	705	701	933	803	1007	1271
	Day-Degrees below 42° Fahrenheit.											
1878–79	1139	1323	1241	1187	1273	967	1106	1011	558	882	725	240
1879–80	631	788	887	1016	976	804	563	651	346	513	336	202
1880–81	1248	1332	1093	984	1068	734	1013	850	465	818	624	181
1881–82	460	505	440	492	490	338	312	287	170	335	188	50
1882–83	776	917	745	764	804	545	622	592	372	658	485	143
1883–84	597	598	459	514	514	329	376	368	174	403	211	15
1884–85	728	806	617	754	778	560	627	580	453	566	490	125
1885–86	884	1009	887	986	981	761	746	777	598	629	514	224
1886–87	802	890	849	989	974	758	653	710	577	581	508	202
1887–88	1080	1089	890	1065	1075	889	824	762	704	660	582	301

TABLE V.

Departures from 42° Fahrenheit in Day-Degrees during the period of 36 Weeks.

(The Results above the base temperature are printed in ordinary type and those below in egyptian.)

Years.	Scotland, North.	Scotland, East.	England, North-East.	England, East.	Midland Counties.	England, South.	Scotland, West.	England, North-West.	England, South-West.	Ireland, North.	Ireland, South.	Channel Islands.	Mean for the British Islands generally.
1878–79	476	544	395	209	287	116	178	111	739	72	498	1255	40
1879–80	131	152	77	95	158	436	473	407	1109	612	1023	1245	493
1880–81	660	524	222	92	23	559	143	120	975	185	714	1495	218
1881–82	414	591	682	820	845	1180	845	935	1442	911	1433	1881	998
1882–83	61	58	167	326	299	787	379	458	955	374	767	1452	490
1883–84	150	383	604	791	771	1135	708	828	1305	810	1327	1800	884
1884–85	14	158	433	500	440	879	409	546	945	593	885	1380	599
1885–86	295	212	79	10	28	404	30	122	545	309	646	1276	232
1886–87	2	108	169	194	169	602	386	323	763	549	874	1434	464
1887–88	579	431	349	250	281	22	119	61	229	143	425	970	15

This Table is merely the combination of values in Table IV., formed algebraically adding the day-degrees above and below 42°.

1883-84. The author's object, however, is not so much to show the effect on vegetation, for which purpose it would probably be desirable to deal only with the period from, say, February, but rather to use this method of registration as an index of heat and cold over a lengthy period. The author would venture the opinion that, to a certain limited extent, the weather throughout the whole period dealt with is a factor in dealing with vegetable growth.

TABLE VI.

TEMPERATURE OF THE AIR IN LONDON FOR THE PERIOD OF EIGHT MONTHS, SEPTEMBER TO APRIL, DURING THE 16 YEARS, 1872-1888.

Years.	1872–3.	1873–4.	1874–5.	1875–6.	1876–7.	1877–8.	1878–9.	1879–80.
	°	°	°	°	°	°	°	°
Mean Maximum	51·8	53·8	51·9	51·3	53·3	52·6	49·0	50·5
Mean Minimum	38·3	39·1	38·2	39·1	41·1	38·9	36·5	36·9
Range	13·5	14·7	13·7	12·2	12·2	13·7	12·5	13·6
Mean	45·1	46·5	45·1	45·2	47·2	45·8	42·8	43·7

Years.	1880–1.	1881–2.	1882–3.	1883–4.	1884–5.	1885–6.	1886–7.	1887–8.
	°	°	°	°	°	°	°	°
Mean Maximum	51·2	53·2	51·7	52·6	52·1	49·2	51·2	48·0
Mean Minimum	37·7	39·8	38·8	40·5	39·4	37·3	37·8	36·7
Range	13·5	13·4	12·9	12·1	12·7	11·9	13·4	11·3
Mean	44·5	46·5	45·3	46·6	45·8	43·3	44·5	42·4

I am indebted to Mr. Gaster for the monthly values from which the above Table has been worked. The figures show that the mean temperature for the eight months from September 1887 to April 1888 is lower than in any other year contained in the Table, but it is only 0°·4 lower than in 1878-79, during which period some intensely cold weather was experienced. It will be seen that the maximum temperature of 1887-88 was lower by 1° than in any other year, but the minimum temperature was not as low by 0°·2 as in 1878-79, and only 0°·2 lower than in 1879-80. The range between the mean maximum and mean minimum was less in 1887-88 than in any other year. A comparison with the Greenwich observations shows that we have to go a long way back for any similar period so cold as that from September 1887 to April 1888. Table VII. shows the mean air temperature in London for the period of eight months, September to April, during the 50 years, 1838-1888.

Table VII. shows that no similarly cold period has been experienced, in the neighbourhood of London, since that embracing the winter of 1854-55, which will be remembered as the time of the Crimean War. The only other instances of an equally low temperature during the

TABLE VII.

1838–39.	1839–40.	1840–41.	1841–42.	1842–43.	1843–44.	1844–45.	1845–46.	1846–47.	1847–48.	1848–49.	1849–50.	1850–51.	1851–52.	1853–53.	1853–54.	1854–55.
43°0	44°1	42°1	44°2	44°5	45°6	42°3	46°2	43°5	45°9	46°0	45°1	45°1	44°5	44°4	44°3	42°3
1855–56.	1856–57.	1857–58.	1858–59.	1859–60.	1860–61.	1861–62.	1862–63.	1863–64.	1864–65.	1865–66.	1866–67.	1867–68.	1868–69.	1869–70.	1870–71.	1871–72.
44°4	44°0	45°6	46°2	43°2	44°0	45°9	46°5	44°8	44°0	47°2	45°4	45°0	46°3	44°0	43°6	45°2
1872–73.	1873–74.	1874–75.	1875–76.	1876–77.	1877–78.	1878–79.	1879–80.	1880–81.	1881–82.	1882–83.	1883–84.	1884–85.	1885–86.	1886–87.	1887–88.	
45°1	46°5	45°1	45°2	47°2	45°8	42°8	43°7	44°5	46°5	45°3	46°6	45°8	43°3	44°5	42°4	

September, mean lower than in 1887 in 5 years.
October, mean in 1887 the lowest during 50 years.
November, mean lower than in 1887 in 13 years.
December, ,, ,, 15 years.
January, ,, 1888 22 years.
February, ,, ,, 7 years.
March, ,, ,, 8 years.
April, ,, ,, 3 years.

50 years were in 1840-41 and 1844-45. The lowest mean temperature for the period in the last half century was only 0°·8 below that of 1887-88.

The Greenwich records have been examined for the nine months from September 1887 to May 1888 inclusive, which show the following results for the respective months :—

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Total 9 months.
Days with temp. above the mean	2	3	12	11	14	7	9	8	13	79
Ditto below the mean	28	28	18	20	17	22	22	22	18	195

The longest period of continuously low temperature, with the daily mean below the average, was one of 31 days, from September 7th to October 7th, 1887.

Mr. Mawley has supplied the following means from his observations kept at Berkhamsted, Herts, for the period of eight months from September 1887 to April 1888 :—

Mean Max.	Mean Min.	Range.	Mean.
46°·4	34°·8	11°·6	40°·7

The coldest month during the period was February, when the mean was only 34°·1.

Mr. Bayard has also supplied the following results from Wallington, Surrey, for the period of eight months :—

Mean Max.	Mean Min.	Range.	Mean.
47°·2	36°·0	11°·2	41°·6

In this situation February was again the coldest month, with a mean temperature of 34°·9. Mr. Bayard shows the average temperature for the whole period to be 2° lower than the corresponding period in 1886-87, and 1° lower than in 1885-86, which is well known to have been severely cold.

Mr. Southall has also supplied the results of observations kept by him at Ross, Herefordshire, for the period of eight months.

Mean Max.	Mean Min.	Range.	Mean.
48°·5	35°·2	13°·3	41°·9

The mean for February was 2°·6 lower than for any other month.

Mr. Mawley has also furnished the departure from average of the past 42 years in the temperature of the soil, at 8 feet below the surface at Greenwich during the eight months.

1887.				1888.			
Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
0°·0	−2°·6	−2°·1	−1°·3	−1°·4	−2°·1	−3°·2	−3°·6

In October the temperature at this depth was the coldest of the period or on record; in November the coldest for 37 years; in December the coldest for 9 years; and in April the coldest during the 42 years or on record.

If time had permitted a much more exhaustive discussion might have been made, and without doubt many more features of interest would have shown themselves. It is not that the period was cold only, but it was dry, and the whole winter was peculiarly free from heavy storms. Probably the feature more intimately connected with the weather experienced was the unusual prevalence of anticyclonic conditions over our Islands, which in its turn was possibly very intimately connected with the early and severe winter on the continent of Europe. For a complete explanation of the conditions we must wait until synchronous charts are published, comprising not only Europe but a very large portion of the Northern Hemisphere.

NOTE ADDED OCTOBER 25TH, 1888.

The period of cold dealt with in the foregoing paper has been prolonged throughout the entire summer of 1888, and was still continuing well into the following autumn. The departures from 42° Fahrenheit in day-degrees, similar to the values given in Table V. (p. 276), but for the 59 weeks from the commencement of September 1887 to about the third week in October 1888, show the day-degrees above 42° to be less in every district than in any corresponding period of the last ten years, and in most of the districts the deficiency was very large. In the South of England the resultant day-degrees above 42° were 1646° below that for the corresponding period in 1883-4, which is equivalent to a difference of about 4° on the mean temperature throughout the whole period of nearly 14 months. The next coldest period in the South of England was 1878-9, which was about 200 day-degrees warmer, a difference equivalent to about 0°·5 on the mean for the whole period. In the South-west of England there was not a single warm week

between March 12th and October 22nd, a period of 32 weeks, and there was only one warm week in the North-west of England and the Channel Islands, whilst there were but four warm weeks out of 59 since the commencement of September 1887 in the North-west of England, and only five warm weeks in the South-west of England.

DISCUSSION.

THE PRESIDENT (Dr. Marcet) was glad that Mr. Harding had taken into account the cumulative temperatures, as these served to show the effect of excess or defect of temperature on the development of vegetation.

MR. HARRIES said the author had alluded to a backward state of the crops as a result of the great deficiency in the amount of accumulated temperature in excess of 42°, but he (Mr. Harries) thought there must be influences at work in connection with plant growth other than those of temperature, rainfall, and bright sunshine included in the *Weekly Weather Report*. Judged by these three elements only, the coming harvest must be a very poor one indeed, but, strange to say, the crops in West Middlesex are making better progress (June 20th) than in the apparently more favourable season of 1886-7, when the accumulated temperature above 42° for the 36 weeks included in this paper was about 530 day-degrees in excess of what it was in the past winter. Rainfall also has been very small, and bright sunshine has averaged 17 per cent. of the possible duration. Yet, notwithstanding this combination of unfavourable circumstances, and the temperature of the soil being below the average, the autumn-sown wheat is going on admirably, and is already earing, a stage which last year was not reached until about the end of June. Rye is exceptionally good, both in quality and quantity. Barley sown on April 7th is coming into ear; winter oats are well forward but short, the later sowings of oats being the least promising of the season. Hay is better and more plentiful than had been expected, while potatoes look remarkably strong and healthy at present. In North Cambridgeshire it has been noted that wheat is in ear earlier than in the hot weather of a year ago, while Irish harvest prospects seem to promise the largest yield in all kinds which has been seen for fifty years past. In Ireland, as with us, accumulated heat is far short of the average, and accumulated cold in excess of the average. Manifestly, therefore, temperature, rain and sunshine form only a portion of what must be considered in relation to growing crops. What the others are, it is difficult to say—perhaps the prevalence of particular winds, and the hygrometric conditions accompanying them, or may be, the predominance of cyclonic or anticyclonic areas over us.

MR. SCOTT remarked that the high maximum temperature of 63° registered at Durham in January was fully borne out by that recorded at surrounding stations.

Mr. C. HARDING said that on comparing notes in his diary respecting the general state of vegetation, he found that in February 1884 the vegetation was in many respects more forward than in May of the present year.

OBSERVATIONS ON CLOUD MOVEMENTS NEAR THE EQUATOR; and on the General Character of the Weather in the "Doldrums."

By HON. RALPH ABERCROMBY, F.R.Met.Soc.

[Received May 1st—Read June 20th, 1888.]

I WISH to lay before the Society the details of observations made on the motion of clouds during four voyages across the Equator and "Doldrums." Great care was taken, especially in the third and fourth journeys, to distinguish between the motions of clouds at different levels.

For practical purposes, clouds may be divided into three series, according to their approximate altitude, viz.:—

1st. High, over 20,000 feet. This includes the high thin forms of cirrus, cirro-stratus, and cirro-cumulus.

2nd. Middle, under 20,000 and over 12,000 feet. This includes the denser forms of the latter two clouds, to which Prof. Hildebrandsson and I have applied the names of "cumulo-cirrus" and "strato-cirrus."

3rd. Low, all clouds under 12,000 feet. This includes all varieties of stratus, cumulus, strato-cumulus and of nimbus.

The difficulties of cloud observations at sea are very great, for there is no fixed point from which to refer the motion of a cloud, unless an edge of the cloud can be caught passing across the sun, the moon, or a star.

Thin high cirrus can rarely be seen when in the full glare of the neighbourhood of the sun, and at night-time cannot be seen at all, except when the moon is up. Even then, unless the cirrus passes across the moon or a star, there is no way of determining the direction of motion. In practice, near the Equator, the best chance of securing observations on high clouds is during the morning and evening twilights, when a few bright stars are visible. Then also, for some reason, much more cirrus is formed than at other hours.

I should like particularly to call the attention of meteorologists to the rarity of the higher clouds in the Trade wind districts, though there seems to be sometimes more cirrus in the neighbourhood of the Equator and "Doldrums." One can sail for days in the Trades without seeing anything but low cumulus, stratus, nimbus, and perhaps some rather high form of strato-cumulus. When a cyclone approaches, then the formation of cirro-stratus and allied clouds is very noticeable.

The direction of the motion was determined by ascertaining as accurately as possible the radiation point of the motion; that is to say, the direction in which the cloud appeared to move during a short interval was produced mentally till it met the horizon, and the bearing of that point of intersection was taken as the direction to or from which the cloud was moving. The apparent curvature of really straight motion over the surface of a sphere must, of course, be neglected at sea.

The first series of observations were made during a voyage from Suez to Melbourne, on board the SS. *Orient*, in the month of February 1885. The detail is given in Table I. The numbers in the columns headed lat. and long. refer to the ship's place at noon.

TABLE I.

SECTION INDIAN OCEAN—ADEN TO CAPE LEUWIN, ss. *Orient*.

1885.	Lat.	Long.	Surface.	Clouds.			Remarks.
				Low.	Middle.	High.	
	N.	E.					
	°	°					
Feb. 26..	9	53	ENE	E	..	..	NE Monsoon
27..	5	58	ENE	E	..	..	,,
28..	2	61	NNE	NNE	E	ESE	,,
	S.						
Mar. 1..	1	64	NNW	NW?	NE	E	NW Monsoon
2..	4	68	NW	NNW	N	E, ESE	,,
3..	7	72	NW	NW	..	..	Diego Garim
4..	7	72	NW	WNW	WNW	..	,,
5..	9	75	NW	SE	SE	..	....
6..	12	79	S	SE	..	..	Cross Doldrums
7..	15	83	SE	SE	..	..	SE Trade
8..	17	87	SE	S	..	..	,,
9..	20	91	E	SE	..	..	Observations few & bad

The most noticeable features of the results are as follows:—Over the North-east Monsoon the clouds came more and more from the East, and in one case from the South-east, which, of course, is the normal vertical succession of the upper currents in the Northern Hemisphere. In about 2° S, the surface wind came from the North-west,—the North-west Monsoon,—small flecks of low cloud from North-east, while some high cirri moved from East at a moderate rate. In 4° S. lat. the surface wind still blew from North-west; the lowest cumulus moved from North-north-west; the next layer of cirro-cumulus—I think I should now have called this cumulo-cirrus—from North; while a still higher layer of cirrus came slowly from East or East-south-east. In 9° S. lat. the surface wind still came from the North-west, and the clouds at a moderate altitude from South-east.

In the "Doldrums," which we only reached in about 12° S. lat., the surface wind was from South, and the low clouds from South-east.

In the South-east Trade, which we carried down to nearly 25° S. lat., there were no observations of any but the lowest clouds, and they came either from the same direction as the surface wind, or from a point or two more to the South.

As a result of the whole, the vertical succession of the upper currents was normal over the North-east Trade Monsoon, but quite abnormal over the North-west Monsoon. The normal currents over a North-west wind in the Southern Hemisphere should come more from the West, whereas here they came more and more from the North and North-east. Over the South-east

Trade the upper winds were abnormal, for the clouds over a South-east surface wind in the Southern Hemisphere usually come from some point more East than the surface wind.

The highest current near the Equator was from the East.

I should also like to call attention to the fact that the surface wind changes under the influence of the earth's rotation almost as soon as the Equator is passed; while the upper currents do not do so. The surface current also goes almost at once into the North-west, and remains blowing from that quarter till the "Doldrums" are reached; whereas, according to theory, the effect of the earth's rotation changes very slowly near the Equator, and the wind should turn gradually from North-east, and get more and more West, the further we get from the Equator.

A similar failure of theory occurs in every Trade or Monsoon district of the world. All over the world, the North-east Trade blows from a constant point—the North-east—for 15° or 20° of latitude; the South-east Trade does the same on the other side of the Equator, and so does the North-west Monsoon, as far as we know, and also the South-west Monsoon in some portions of its area, notably in the Bay of Bengal, north of 10° N. lat.

The theory at present most in vogue requires that the wind should not remain parallel to any direction as it flows down any gradient, and that the deflection due to the earth's rotation is the same in every azimuth; but this does not accord with the facts observed in the tropics.

The peculiar squally character of the North-west Monsoon is well known, and contrasts with the peculiarly fine weather of the North-east Monsoon. No explanation has ever yet been suggested why crossing the Equator should alter the weather in a current of air. Can the reason be that there is an abnormal vertical succession of the upper currents between the Equator and the "Doldrum"?

In the following year, 1886, I made another voyage across the same region at the same season, but in an opposite direction, to verify the first set of observations. Owing to the experience gained, these observations are much fuller and more complete than those in the previous voyage. The details are given in Table II., where, as before, the latitudes and longitudes refer to the ship's place at noon.

The most noticeable features are as follows:—Over the South-east Trade, north of 25° S. lat., the low or middle clouds came from points more East than the surface wind, and this is in accordance with the usual vertical succession of the Southern Hemisphere. No high cirrus was ever observed.

We found no "Doldrum," but ran straight from the Trade under a bank of cloud into the North-west Monsoon in about 12° S. lat. In that Monsoon the low and middle clouds always came a little more from the North than the surface North-west wind; or in the manner of the upper winds of the Northern Hemisphere. During the time that we were in this most interesting region, I usually managed to get about seven observations a day, beginning about 5 a.m., when, as before mentioned, high clouds can be most advan-

TABLE II.

SECTION INDIAN OCEAN—CAPE LEUWIN TO COLOMBO, 1886, ss. *Valetta*.

1886.	Lat.	Long.	Surface.	Clouds.			Remarks.
				Low.	Middle.	High.	
	S.	E.					
	°	°					
Feb. 6.....	25	106	S	SW	..	..	SE Trade
7.....	21	102	S	..	SE	..	,,
8.....	17	99	SE	..	E	..	,,
9 10 a.m.	13	76	SSE	E	..	..	,,
4.30 p.m.	..	..	SE	..	E	..	,,
6 p.m.	..	..	SE	NE	NNE or N	..	,,
7 p.m.	..	..	N or NNW	NE	..	..	NW Monsoon
11.30 p.m.	..	..	NNW	NNW	..	..	,,
10 5 a.m.	..	..	NNW	NNW	..	..	,,
9 a.m.	9	92	NW	NNW	..	..	,,
2.15 p.m.	..	..	W	W	NW	..	,,
4 p.m.	..	..	NNW	WNW	N	..	,,
5 p.m.	..	..	NW	..	N	E	Cirr. very slow
6 p.m.	..	..	NW	..	..	ENE	NW Monsoon
7 p.m.	..	..	NW	..	N	NE	,,
11 5.30 a.m.	..	..	WNW	..	NNW	S	,,
10 a.m.	5	89	WNW	..	WNW	..	,,
4.30 p.m.	..	..	W	..	WNW	..	,,
6 p.m.	..	..	W	..	..	E	,,
7 p.m.	..	..	W	..	WNW	..	....
11 p.m.	..	..	Calm	..	NW	..	....
12 3.15 a.m.	..	..	Calm	..	..	..	No Cloud
5.30 a.m.	..	..	Calm	NNW	..	..	....
10 a.m.	..	..	NW	..	NNW	..	....
Noon	2	36	N	..	N	..	....
5 p.m.	..	..	NNW	NNW	..	..	....
7.30 p.m.	..	..	N	N	..	..	....
11 p.m.	..	..	NNW	NNW	..	..	....
13 3 a.m.	..	..	Calm	N	..	..	....
5.30 a.m.	..	..	NNE	N	NE	..	NE Monsoon
8 a.m.	..	..	NNE	..	NW?	NE	,,
	N.						
10 a.m.	2	83	NNE	..	NE	..	,,
2 p.m.	..	..	NE	..	N	..	,,
2.45 p.m.	..	..	NE	..	NNE	..	,,
5.30 p.m.	..	..	NNE	NNE	..	..	,,
10.30 p.m.	..	..	NNE	NNE	..	..	,,
14 3 a.m.	..	..	..	NNE	..	..	,,
5.30 a.m.	..	..	NNE	NNE	..	..	Cloudless
9 a.m.	Point	Galle	N	N	..	..	....

tageously observed. All the high cirri moved from East or North-east, except on one occasion when they came from South.

The weather in the North-east Monsoon, which we picked up on the Equator, was so clear that I only obtained one observation of cirrus, which came from the North-east when the surface wind was North-north-east. The lower clouds were usually from the same direction as the surface wind, though on one or two occasions they came from a point more Northerly than the surface wind. The highest currents near the Equator came from some point of East. The results entirely confirmed those obtained during the previous voyage.

I have unfortunately no detailed records of the wind force, but we found on this voyage, what I have been assured by experienced sailors is usually the case, that the wind falls light just on the Equator where the North-east Monsoon turns into the North-west. Here, too, theory is entirely at fault; if the gradient lies across the Equator there seems no reason why the wind should not cross the Line in an unbroken sweep.

The maps of the Bay of Bengal, recently published by the Indian Government, show that something similar occurs in the south of that Bay during the South-west Monsoon. A ship coming from south of the Line finds the South-east Trade fall light near the Equator, then she experiences light variable winds—preponderatingly from the West—for the first 10° North, before she enters the strong South-west Monsoon of the head of the Bay. The reason of the hesitation in the sweep of the currents across the Equator in either Monsoon cannot be explained at present, but the fact should be noted by every student of the general circulation of the atmosphere.

I shall now give the details of two weather sections across the Atlantic "Doldrums." The first was taken from Rio Janeiro to Teneriffe in the year 1885. This was a very barren voyage so far as cloud observations were concerned, as no true cirrus was ever seen, and middle level clouds on only two occasions. However, the actual observations are given in Table III.

TABLE III.

SECTION ATLANTIC—RIO, TENERIFFE, ss. *Tongariro*.

1885.	Lat.	Long.	Surface.	Clouds.			Remarks.
				Low.	Middle.	High.	
	S.	W.					
June 26.....	° 27	° 46	SW	NW	..	..	....
8 p.m...	26	45	NE?	N	..	..	Near Rio Janeiro
29.....	19	39	NW	NE	..	..	....
30	14	37	NNE	NW	..	..	....
July 1.....	10	34	E	ENE	..	..	SE Trade
2.....	5 N.	32	SE	ESE	..	..	,,
3	1	30	E	ENE	..	..	,,
4 6 a.m...	4	28	ESE	ENE	..	..	,,
11 p.m...	..	..	NNE	NNE	..	..	....
5 6 a.m...	8	25	NNE	NEbN	..	..	Doldrums
8 a.m...	8	25	NNE	..	..	ESE	....
6 6 a.m...	13	23	SE	..	E	..	Doldrums
2 p.m...	..	..	NE	NE	..	..	NE Trade
8	22	19	ENE	..	NNE	..	,,

The principal features are that, with one exception, while south of the Equator, the low or middle clouds came from some point to the right of the surface wind when you stood with your back to it; that is to say, in the normal manner of the Southern Hemisphere. But north of the Line—when, for reasons which need not be discussed here, the South-east Trade does not

turn to South-west as might have been expected—the upper currents continued to follow the vertical succession of the Southern, and not that of the Northern Hemisphere, that is to say, the upper currents over the surface South-east wind continued to come from some more Easterly point.

In the "Doldrums" also, which extended from about 8° to 13° N., the same rule obtained, and the middle layer, over some cat's paws of South-east wind, drove from the East.

In the North-east Trade I only obtained one unsatisfactory observation in lat. 22° N., 19° W., which gave a middle layer of North-north-east wind over an East-north-east surface Trade.

The highest observed current—middle level only– over the "Doldrums" was from the East.

The second section across the Atlantic was taken in December 1885, during a voyage from Dartmouth to Cape Town. The details are given in Table IV.

TABLE IV.

SECTION OF THE ATLANTIC—TENERIFFE TO CAPE TOWN, ss. *Drummond Castle.*

1885.	Lat.	Long.	Surface.	Clouds.			Remarks.
				Low.	Middle.	High.	
	N.	W.					
	°	°					
Dec. 3.....	30	14	ENE	E	..	SE	Near Teneriffe
4.....	25	16	NE	NE	S	..	NE Trade
5.....	20	18	NNE	..	SbW	..	,,
6.....	15	17	E	..	SbW	..	Off Cape Verde
7.....	10	16	NNE	SbW	W	..	NE Trade
8 9.30 a.m...	5	14	NNE	SE	E	..	,,
11 a.m.....	..	..	O	..	..	E	,,
3.30 p.m...	..	..	SbW	SE	..	..	Doldrums
10.30 p.m...	..	..	SbW	S	SE	..	SW Monsoon
9.....	1	11	SbW	S	SE	E	,,
	S.						
10.....	2	8	SbE	SbE	..	..	SE Trade
11.....	6	7	SSE	SSE	SSE	..	,,
12.....	10	2	SbE	SSE	..	..	,,
13.....	14	0	SSE	..	SSE	..	,,

The most noticeable features are that, in the North-east Trade, from 30° N. lat., down to the "Doldrums" in 5° N., the upper layers of cloud invariably came from some point more to the left as you stood with your back to the wind. As far as 20° N., the middle layer of cloud came from S. by W., and in 10° N. This current had descended to the level of the lower clouds, while the middle clouds drove from West. It should be particularly noted that the South-west upper current does not flow directly over the North-east Trade, but that the current goes round in a regular manner as we ascend vertically. The old idea of a great sweep of North-east Trade with a South-west Anti-Trade above is quite erroneous.

But as we entered the "Doldrums" in 5° N., a totally different wind system became apparent. I could just detect, over the oily calm of that region through the universal gloom and haze, a middle current from the East,

and when in a few hours we picked up the South-west Monsoon of the Gulf of Guinea, the low clouds drove from South-east.

This vertical succession continued till we reached the Equator, and the single observation which I obtained of high cirrus in 1° N. showed an Easterly current at that level.

Thus from 5° N. down to the Equator the succession of the upper winds was that proper to the Southern Hemisphere; and this was the more curious, because the surface wind had the set proper to the Northern Hemisphere.

But the greatest interest in this last observation is to be found in the extraordinary analogy which this wind system over the Gulf of Guinea presents to that over the North-west Monsoon which has just been described. There, when the North-east Monsoon turns to North-west, directly it has crossed the Equator, the vertical succession remains that proper to the Northern Hemisphere. Here in the Gulf of Guinea, in the same way, the South-east Trade turns to South-west as it crosses the line, while the vertical succession remains that of the Southern Hemisphere.

After crossing the Equator on this voyage, the upper currents over the South-east Trade were either identical in direction with the surface wind, or else a very little more Easterly; that is to say, in accordance with the usual law of vertical succession.

Here, too, as in the other three voyages, the highest currents over the Equator and "Doldrums" came from points of East. This discovery of an Easterly current near the meeting of the Trades was quite unexpected, and coincides in a remarkable manner with the curious flow of dust from the volcanic eruption of Krakatoa.

The researches of the Krakatoa Committee of the Royal Society have conclusively proved that the dust and ashes from that volcano travelled in a narrow stream rapidly round the earth from an easterly direction nearly along the line of the Equator. This was at the end of August, when the South-west Monsoon was beginning to fail.

The labours of that Committee give a velocity of about 80 miles an hour for the propagation of the dust. Of course, I had no way of estimating the velocity of the upper clouds, but they did not appear to me to be travelling with anything like that high velocity. The Krakatao dust was, however, at a much higher level than any clouds I have ever observed. It may be mentioned, with reference to this volcanic dust, that during my voyage across the Indian Ocean in February 1885, the so-called "Bishop's Ring" round the sun was repeatedly observed; and there is no doubt that this ring was due to the refraction or diffraction caused by light particles of volcanic dust which still remained suspended in the atmosphere.

The principal object of all the observations described in the present paper was to try and discover the real nature of the circulation of the atmosphere at the meeting of the Trades. This has always appeared to me to be one of the most vital problems of meteorology; but I regret to say that the question remains as yet unsolved.

There are two theories on the subject. The popular one is that the two

surface, North north-east; low cloud, North-east by North, cirrus motionless. 8 a.m. Hazy blue sky; surface, North-north-east, light high wisps cirrus, East-south-east. About 2 p.m. Surface to East, very light, and by 7 p.m. to South-east, very light.

6th. Lat. 13° N. long. 23° W. 6 a.m. Surface, South-east, light; low fleecy cirro-cumulus from East; all morning nearly overcast and no observation at noon. About 2 p.m. the wind went into the North-east fresh, and we instantly felt a new chilly air of the North-east Trade, while big low masses of cloud scudded from the North-east below the high cirro-cumulus, whose direction could not be ascertained.

This was a typical section of the Atlantic at this summer season;—a belt of Variables, 300 or 400 miles across, between the two Trades. The North-west squall on leaving the South-east Trade is, I am informed, very common there; but this, being north of the line, must not be supposed to be the same as the squall which was experienced south of the Equator at the meeting of the South-east Trade and the North-west Monsoon. In the "Doldrum" belt North-east and South-east airs alternated, while the clouds seem to keep more from the East or South-east. The entry into the North-east Trade region was sudden and without any squall or rain. The fine weather in the whole "Doldrum" belt is very noticeable, and it is evident that there could be no great uprush of air under a nearly blue sky. A photograph of this "Doldrum" sky was exhibited by myself before this Society in January 1887.

The record of the voyage from Dartmouth to Cape Town has also unfortunately been lost, though luckily I had a memorandum of the upper cloud observations which is reproduced in Table IV., I cannot, therefore, give a detailed account of the weather in the "Doldrums;" but a couple of hours run in an oily calm took the ship from the North-east Trade into the South-west Monsoon of the Gulf of Guinea without much rain. There was no broad belt of Variables as in the former voyage so much farther west, and in July instead of in December.

I cannot from these observations form any definite opinion as to the true nature of the circulation of the atmosphere at the meeting of the Trades; but I should like to call attention to the fact that in none of these four cases was there any evidence of an extensive uptake of air. The heavy showers where two currents actually seemed to come into collision were very local, and certainly extended a very short distance vertically. If there was any rapid ascension of "Doldrum" air—which contains at least 12 grains of water in the cubic foot—the rainfall would be tremendous. We know this by what happens when such moist currents are turned upwards by the obstruction of a mountain chain; but nothing of the sort has been observed in the "Doldrums" out at sea. I can only hope that this subject may attract the attention of those who have the opportunity of making suitable observations.

Summary.

The results of this paper may be summarised as follows:—I detail the results of observations during four voyages across the Equator and

"Doldrums," with special reference to the motion of clouds at various levels. Two voyages were across the Indian Ocean during the season of the North-west Monsoon, and two across the Atlantic in the months of July and December.

Attention is called to the rarity of the higher forms of clouds in the Trade wind districts; though cirrus is sometimes more frequent in the neighbourhood of the "Doldrums."

In the Indian Ocean, the upper currents over the North-east Monsoon and the South-east Trade were both more Easterly than the surface winds; that is in accordance with the general law of vertical succession of the upper winds proper to their respective hemispheres.

But over the North-west Monsoon—between the Equator and the "Doldrums," in about 12° S.—the vertical succession is that of the Northern and not of the Southern Hemisphere; that is to say, the upper currents come more and more from the North, North-east, and even from the East. The highest clouds over the "Doldrums" were from East.

It is suggested that the well-known squally rainy character of the North-west Monsoon may be due to this abnormal vertical succession of the upper currents.

It is pointed out that the North-east Monsoon falls light as it crosses the Equator, though the current increases again in force as the North-west Monsoon before reaching the "Doldrums." Something similar is observed in some districts when the South-east Trade crosses the line to become the South-west Monsoon. In both cases a belt of equatorial calm—different from the "Doldrums"—has stronger winds on either side. No theoretical explanation has yet been suggested for this curious falling of the wind.

It is also shown that no theory yet explains either the rapid change of North-east into North-west, and of South-east into South-west winds near the Equator; or the great extent of latitude through which any Trade or Monsoon blows without any change of direction. Theoretically, the rotation component of wind changes very slowly near the Equator, while, practically, the *surface* wind changes almost directly it has crossed the Line either way; and wind directed down a long gradient from north to south should curve instead of remaining constant in direction.

In the Atlantic, the upper winds over the North-east Trade were almost without exception from South-east or South-west; and those over the South-east Trade—while south of the line—more East or North-east. This is in accordance with the usual law of vertical succession. But between the Equator and the "Doldrums"—always north of the line in the Atlantic—the upper currents were more Easterly than the surface winds, both in the western portion of the ocean over a South-east wind and in the South-west Monsoon of the Gulf of Guinea.

Thus there is a belt of the world north of the Equator with an abnormal vertical succession of upper currents in the Atlantic, precisely analogous to the belt in the Indian Ocean south of the line, during the season of the North-west Monsoon. The highest clouds observed over the Atlantic "Doldrums" came from the East.

It is shown that this discovery of a high Easterly current over the "Doldrums" accords with the observations on the flow of dust from the volcanic eruption of Krakatoa.

The nature of the general circulation of the atmosphere near the "Doldrums" is then discussed, as regards the theory that the Trades, after meeting, rise and fall back on themselves; or, according to the suggestion of Maury, that the Trades interlace and cross the Equator; or as following the analogy of Dr. Vettin's experiments on smoke. It is shown that the materials at present available are insufficient to form a definite conclusion, but details are given of the general character of the weather and of the squalls in the "Doldrums," with a view of showing what kind of observations are required to solve this important problem.

The old idea of a deep Trade—with a high opposite current flowing overhead—is certainly erroneous; for there is always a regular vertical succession of the upper currents as we ascend, according to the hemisphere.

DISCUSSION.

Capt. WILSON-BARKER, in a note to the Secretary, said:—

"Summarised results of personal observations will always be valuable. Those by Mr. Abercromby require some care in theorising from such scanty material. A letter of mine appeared in *Nature*, December 8th, 1887, which gave the results of observations made in the Tropical Regions of the Atlantic during 16 passages across, each, on an average, occupying 3½ weeks, which allowed of observations being taken under good circumstances, as the ship was many times becalmed. The general result of these observations was, that in the South-east tropical Trade wind region, which extends on an average to about 5° N latitude, the movement of the upper clouds was from North-west by West, while in the North-east tropical Trade wind region, extending from 5° N to 23° N latitude, the movement of the upper clouds was from South-west. The movements of the middle layer clouds (in which I include nearly all cirro-cumulus and such-like clouds) were uncertain, but were often from an Easterly point. These cirro-cumulus forms are generally reported as upper clouds, whereas many of them are middle layer clouds, only a few extending into the true upper regions of the atmosphere. Returns recently received from Grand Bassam on the Ivory Coast, report all upper cloud movements from South-west during the last four months. During three months spent in Suakim, April, May and June 1885, and three months in Massowah, December, January and February 1888, all movements of upper clouds were from a South-west point. As a general rule, I find little difficulty in distinguishing the movements of cirrus at sea."

Capt. TOYNBEE said that the Fellows were greatly indebted to Mr. Abercromby for doing such good work during his travels round the world. He (Capt. Toynbee) had extracted the observations of upper clouds contained in some of his own logs for a district embracing the North Atlantic, from the Equator to the verge of the Noth-east Trade. The results of his observations were contained in the following statement:—

ON OF UPPER CLOUDS OVER NE TRADES IN MARCH. WIND NE. BETWEEN 24° N AND 13° N.

si- on.		Upper Clouds.							
Long. W.	Wind.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
°									
40	ENE	..	..	..	..	..	..	..	Cir-c. WNW
33	NNE	..	..	..	..	..	Cir-c. WbS	..	..
38	NE	..	..	..	..	..	..	..	Cir. NWbW
37	NNE	..	..	..	..	..	Cir. WbS[1]	..	..
35	NEbE	..	..	..	..	..	..	..	Cir-c. Cir-s. NWbN
34	NE	..	..	..	..	..	Cir. SW	..	..
33	NEbN	..	..	..	..	..	Cir. SW	..	..
n n.	NE	..	..	..	..	..	WSW	..	NWbW

[1] In 15° N 37° W. Str. from SE.

MARKS.—In 27° N 41° W. Wind WNW. Cir c. from SW. From the northern limit of Trade down to 13° N the Upper Clouds were either from the SW or NW, the means being W and NWbW.

ON OF UPPER CLOUDS OVER NE TRADES IN APRIL. WIND N, NE, E OR CALM. BETWEEN 26° N AND 5° N.

si- n.		Upper Clouds.							
Long. W.	Wind.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
°									
45	E	..	..	..	..	..	..	..	Cir-c. WbN
45	Calm	..	..	..	..	..	..	..	Cir-c. WNW
45	NbE	Cir-c. N	..	..	..	..	..	..	..
39	NbE	..	..	..	..	..	..	Cir-s. W	..
39	Calm	..	..	..	..	..	..	..	Cir. WNW
38	NE	..	..	..	..	..	..	Cir. W	..
37	NbE	..	..	..	..	..	..	..	Cir-s. WbN
37	NbE	..	..	..	..	..	..	Cir s. W	..
36	Calm	..	..	..	..	..	..	..	Cir-c. WNW
36	Calm	..	..	..	..	..	Cir-s. WbS	..	..
35	NE	..	Cir-s. NEbE	..	..	..	Cir. SWbS	..	..
27	ENE	..	Cir. EbN	..	..	..	..	..	..
27	NE	..	..	..	..	..	Cir-s. SWbS	..	..
22	ENE	..	Cir-s. NbE	..	Cir-c. ESE	..	..	..	..
n 1.	NE	N	NE	..	ESE	..	SW	W	WNW

MARKS.—In 29° N 42° W, Wind SSW; Cir. Cir-c. from WNW. In 27° N 45° W, Wind ir-c. from WbN. It will be seen that in 29° and 27° N, when the Wind was S, the Upper ds came from WNW; and from 26° N, where the NE Trade was blowing, down to 14° N, Jpper Clouds were chiefly from the NW or W, while from 14° N to 5° N, where the Trade still blowing, they were principally from SW and NE.

MOTION OF UPPER CLOUDS OVER NE TRADES AND SW MONSOONS IN JULY. BETWEEN 27° N AND 9° N.

Position. Lat. N.	Position. Long. W.	Wind.	Upper Clouds. N.	NE.	E.	SE.	S.	SW.	W.	NW.
°	°									
27	23	NEbW	..	..	..	Cir-c. EbS	..	..	..	..
13	27	N	..	..	..	..	..	..	..	Cir-s. WNW
12	26	ESE	..	..	..	..	..	Cir-c. SSW	..	..
10	25	SSW	..	Cir-c. ENE	..	..	..	..	..	..
10	25	SSW	..	Cir-c. ENE	..	..	..	..	..	..
9	24	SSW	Cir-c. WNW	..	..	..	..	..	..	..
9	23	S	..	..	..	Cir-c. ESE	..	..	..	..
Mean Dirn.		..	NNW	ENE	..	EbS	..	SSW	..	WNW

REMARKS.—Here it is shown that from 27° to 12° N, when the wind was chiefly E, the clouds were chiefly from some W quarter; whilst in 10° and 9° N, where the wind was chiefly SSW, the clouds were chiefly from some E quarter.

MOTION OF UPPER CLOUDS OVER THE SW MONSOON AND THE SE TRADES IN AUGUST. BETWEEN 8° N AND 2° N.

Position. Lat. N.	Position. Long. W.	Wind.	Upper Clouds. N.	NE.	E.	SE.	S.	SW.	W.	NW.
°	°									
8	18	SSW	..	..	..	..	..	..	..	WNW
7	21	S	..	..	..	..	..	Cir-c. SSW	..	..
4	20	SE	..	Cir-c. ENE	..	..	..	..	..	..
4	19	S	..	Cir. ENE[1]	..	..	..	..	..	..
2	15	SSE	Cir-c. NNW	..	..	..	..	..	..	..
Mean Dirn.		SSE	NNW	ENE	..	..	..	SSW	..	..

[1] In 4° N 19° W. Str. from NW. No clouds with wind.

REMARKS.—In 2° N 22° W. Str. from WSW. Wind SSE. Cir-c. almost stationary.

MOTION OF UPPER CLOUDS OVER NE TRADES AND SW MONSOONS IN SEPTEMBER. BETWEEN 21° N AND 5° N.

Position. Lat. N.	Position. Long. W.	Wind.	Upper Clouds. N.	NE.	E.	SE.	S.	SW.	W.	NW.
°	°									
21	21	N	..	..	..	Cir-c. SE[1]	..	..	..	..
16	21	NNE	..	..	..	Cir-c. SE	..	..	..	..
15	21	N	..	Cir-c. NNE	..	..	.	..	..	..
13	21	SW	..	Cir-c. NNE	..	..	..	..	..	..
7	18	WSW	..	..	..	Cir-c. SSE[2]	..	..	..	..
5	15	S	..	Cir-c. ENE	..	..	..	..	..	..
Mean Dirn.		..	..	NEbW	..	SEbE	..	..	..	..

[1] Fog Clouds from NE. [2] Lower Clouds from NNW.

REMARKS.—Here from 21° to 5° N the wind was N down to 15° N, and SW from 13° to 5° N. These Cir-c. observations were recorded over each of the wind systems, all were E, but chiefly SE over the N wind and NE over the SW wind.

Capt. MACLEAR said we had no means of satisfactorily determining what was the height at which clouds were visible, and knew nothing of the circulation or flow of currents in the regions above the clouds. [Captain Maclear wishes to add that if the upper currents have a speed of 80 miles, as stated for the Krakatoa dust, the greatest care will have to be taken in ascertaining the real direction of the highest clouds visible before we can discuss the circulation.]

Mr. C. HARDING said he could not but admire the way in which Mr. Abercromby had so skilfully handled so few observations, but he thought it was unwise to place much reliance on such a paucity of material. The weather in the Equatorial Doldrum had been discussed in the Meteorological Office, and the results of this discussion had been published. He had carefully gone through the cloud observations in this work, comprising several hundreds, and had taken out the directions of cirrus and cirro-stratus, plotting the results on a rough diagram, which he exhibited. This diagram did not altogether bear out the observations given in Mr. Abercromby's Paper, and he was disposed to doubt the theory as to the return Trade suggested by Mr. Abercromby, and preferred to uphold the old theory.

Mr. ABERCROMBY, in reply, said he did not attempt to put forward any theory, but merely gave the results of his own observations. He had principally directed his attention to the weather and cloud movements in the district where the Trades meet, as he held the problem of the air circulation in that neighbourhood to be a very important one. He considered Mr. Harding's diagram was extremely interesting, but his own experience from observations made in this district was that cirrus and cirro-stratus clouds were most rarely to be seen. His own observations of the weather in the Doldrums led him to believe that the amount of rain which was said to fall in this region was greatly exaggerated.

The THUNDERSTORMS of MAY 18th and 19th, 1888.

By WILLIAM MARRIOTT, F.R.Met.Soc.,

Assistant Secretary.

[Read June 20th, 1888.]

THE thunderstorms of May 18th and 19th were both of a remarkable character.

The storm on the night of the 18th-19th passed across England in a direct line from South to North, at the rate of 50 miles an hour.

Thunder was first heard at Christchurch, Hants, at 8.15 p.m. Lightning was first seen at Totton, near Southampton, in the south at 7.58 p.m. The storm then progressed in a northerly direction, thunder being heard at Beckford, near Tewkesbury, at 9.52, and at Worcester about 10.0. The storm passed a little to the west of Birmingham, where the lightning was incessant and very vivid between 10 and 11 p.m. Thunder was heard at Upper Tean at 10.40; at Manchester at 11.59 p.m.; at Garstang at 0.30 a.m.; at Windermere about 1.30; at Kirkby Thore at 1.45; at Carlisle about 2.0; and at Edinburgh about 4 a.m. The storm evidently reached Cupar Fife at 4.5 a.m., as the Fife and Kinross Asylum was struck by lightning at that time and set on fire.

In addition to the reports of thunder given above, many observers in various parts of the country saw lightning during the evening and night of the 18th. Where they have given the time and direction in which the lightning was seen, it has been found that these agree precisely with the positions of the thunderstorm at those times, although the observers, in two cases at least, were more than 100 miles from the storm.

At Babbacombe, near Torquay, lightning was seen in the East-north-east at 8.30 p.m. and in the North-east at 9.12; at Harestock, in the South-west, at 8.25, and in the North-north-west at 10.0 and later; at Mere, in the North-east at 9.0; at Churchstoke, in the South-east at 9.45; at Berkhampsted, in the North-west at 10.0; at Upper Tean, in the South at 10.10, and in the North-west at 11.30; at the Kew Observatory, in the North-west at 10.30; at Manchester, in the North-west at 0.50 a.m.; at Chester, in the North at 1.0; and at Kirkby Thore, in the North at 3 a.m.

Most of these times are shown on fig. 1, the times of thunder being given in large figures, and the direction in which the lightning was seen by long arrows, with the time in small figures.

It will thus be seen that this thunderstorm came up from the English Channel about 8 p.m. on the 18th, passed across the country in a North by

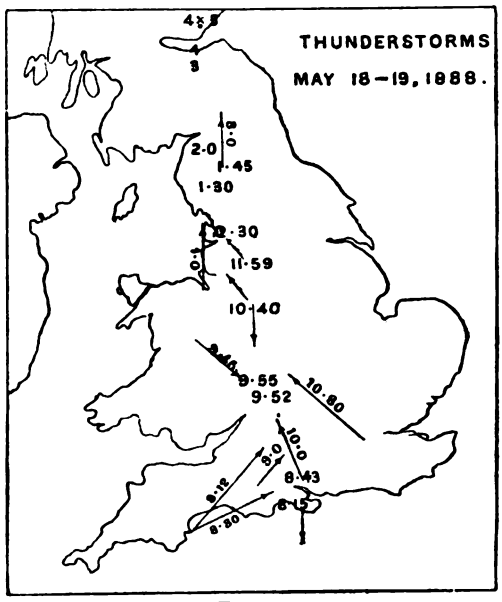

FIG. 1.

West direction, and reached the Firth of Forth by 4 a.m. on the 19th. The distance traversed is over 400 miles, the rate of progression of the storm being 50 miles an hour.

On May 19th a thunderstorm of slight intensity passed across the South-east of England in an East-north-east direction. Thunder was first heard at Idsworth, near Horndean, at 2.45 p.m., and at Lynsted, near Sittingbourne, about 5.0. Thunderstorms of a very violent character also occurred over almost the whole of the South of Scotland and the North of England north of the Mersey during the afternoon of this day. Fig. 2 shows the times of the storms at several places. These storms are of quite a different character to that which passed across the country the previous night; that progressed rapidly in a direct path, while these storms prevailed over a very large area, were slow in motion, and in fact hung about the neighbourhood for several hours.

Much damage was done by the lightning, and many persons were killed. The crosses on Fig. 2 indicate the places where fatalities occurred.

The thunderstorm which burst over Glasgow was, as Prof. Grant says, "the most awful occurrence of the kind which has been recorded in the annals of the Observatory."

The following is a local account of the storm :—

The previous day the atmosphere had been close and sultry, but to a certain extent cooled in the evening by a slight thunderstorm and a heavy fall of rain. Nevertheless on Saturday morning there was again every indication that the heavy masses of dull lurid clouds hanging over the city were heavily charged with electricity, while the air, which was almost undisturbed by the usual currents,

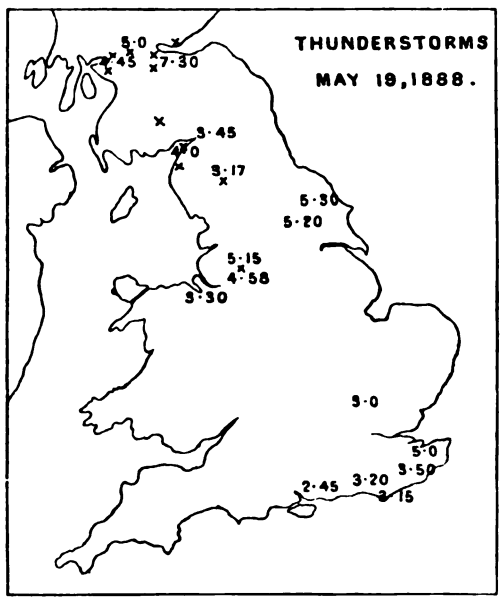

FIG. 2.

was hot and stifling, causing among the people a general feeling of lassitude. During the forenoon a short glimpse of the sun was obtained, but in no other way were the atmospherical conditions changed until about 3 p.m. At that hour the rumbling of thunder was heard, first in the distance, then gradually nearer the city, when rain began to fall in moderate quantities. This had only continued for a short time, when the storm itself burst over the city with an alarming fury that continued with unabated strength for fully an hour. The rain at first fell in torrents, but immediately gave place to a dense shower of hail-stones, resembling in size the proverbial pigeon's egg. This was again followed for the next half-hour without cessation by alternate blinding sheets of water and dense masses of hail, which fell with so great a force as to cause the particles to roll for many yards before coming to rest. During all this time the commotion in the clouds was appalling; forked lightning shot hither and thither in all directions athwart the sky, while the roll of the thunder, which was well-nigh incessant, resembled the discharge of heavy artillery. A slight breeze sprang up after the storm had lasted some time, and breathing became tolerable. The thunder and lightning, however, continued, and at short intervals rain and hail fell in drenching showers. The storm seemed to travel in a circle around the city, and showed no signs of abating until about 5 p.m., when a lull in the fury of the elements took place. It was quite evident, however, that the storm had not spent itself, and after a lapse of about two hours it again broke out. Rain fell heavily, but in half an-hour the atmosphere became clearer and the air cooler, while the thunder gradually died away. From reports received from various parts of the country it appears that the thunderstorm was not of a local nature, but that it extended over a considerable area of country. From many districts reports have been received giving particulars of various accidents to property and farm stock by the lightning, but certainly the most serious occurred in our own neighbourhood.

Mr. Muirhead, F.R.Met.Soc., says :—"This storm was the most magnificent I ever witnessed, the lightning playing in enormous flashes from cloud to cloud, cloud to earth, and earth to cloud again. The longest and brightest

flash occurred at 4.45 p.m. It was preceded by a very bright one, violet in colour, straight from cloud to earth; viewed from the slope below the University it appeared to be quite the other side of Glasgow Green (South-east). The long flash seemed to issue from the same cloud, and, flickering towards the Exhibition Buildings, it travelled away West-south-west again into the clouds. (By Ordnance map I judged this flash to have been *six miles long.*)"

During the storm there was a heavy shower of hail, the stones of which, Prof. Grant states, appeared to be equal in magnitude to a pigeon's egg.

DISCUSSION.

Capt. TOYNBEE said that it would not be necessary for the storm to travel at the rate which the map of its path seemed to indicate, as the change of position was possibly due to a re-formation at the point of first contact of two opposite currents of air along the line of its track.

Mr. SYMONS said some thirty years ago he had worked at thunderstorms, and on very similar lines to those adopted by Mr. Marriott in his remarks upon the storms of May 18th and 19th. He remembered one instance (April 12th, 1857,) which fully bore out the great distance from the thunderstorm area at which lightning could be seen. The thunderstorm was in progress in the English Channel near Cape Gris Nez, and the lightning was seen as far north as Nottingham. It therefore appeared to be perfectly possible to see the reflection of lightning at a distance of 175 miles.

Mr. MARRIOTT said he was unable to give any definite information concerning the wind circulation during these thunderstorms, but the question would be more thoroughly gone into when the whole of the information concerning thunderstorms, which the Society was now collecting, was finally discussed by the Thunderstorm Committee.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

MAY 16TH, 1888.

Ordinary Meeting.

WILLIAM MARCET, M.D., F.R.S., President, in the Chair.

LEONARD WILLSON GATWARD, Bancroft, Hitchin; and
NIMROD SIMMONS, Glendale, Clifton, Bristol,
were balloted for and duly elected Fellows of the Society.

Prof. DANIEL COLLADON, of Geneva,
was balloted for, and duly elected an Honorary Member of the Society.

The PRESIDENT, on behalf of Mons. KAMMERMANN, of Geneva, described and presented to the Society one of Kammermann's Wet Bulb Thermometers.

The following Papers were read:—

"REPORT OF THE WIND FORCE COMMITTEE ON EXPERIMENTS WITH ANEMOMETERS CONDUCTED AT HERSHAM." Drawn up by G. M. WHIPPLE, B.Sc., F.R.Met.Soc., and W. H. DINES, B.A., F.R.Met.Soc. (p 253.)

"On the Measurement of the Increase of Humidity in Rooms by the emission of Steam from the so-called 'Bronchitis Kettle.'" By William Marcet, M.D., F.R.S., President. (p. 263.)

Several portions of a Tree struck by Lightning, and sent to the Society by Mr. F. Slade, F.R.Met.Soc., were exhibited to the Meeting.

June 20th, 1888.

Ordinary Meeting.

William Marcet, M.D., F.R.S., President, in the Chair.

Frank de Beauchamp Collenette, L.R.C.P., Silverdale, Staffordshire;
John Ewart, M.R.C.S., Grimsby;
Franz Albert Veltschow, 53 Parliament Street, S.W.; and
John Tayler Wills, F.R.G.S., 273 Vauxhall Bridge Road, S.W.,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"First Report of the Thunderstorm Committee.—On the Photographs of Lightning Flashes." Drawn up by the Hon. Ralph Abercromby, F.R.Met.Soc. (p. 226.)

"The Thunderstorms of May 18th and 19th, 1888." By William Marriott, F.R.Met.Soc. (p. 296.)

"Hailstorm at York, May 19th, 1888." By H. M. Platnauer. (Communicated by Robert H. Scott, F.R.S., F.R.Met Soc.)

Hail lasted from about 5.20 to 5.30 p.m. The sun was shining during a good part of the time.

Two or three vivid flashes of lightning occurred during the storm. The hail was mingled with rain, the latter much in excess.

The hailstones seemed to be of three kinds:—

1. Oval flattened stones, three-eighths to half-an inch along the major axis, and one-eighth to three-sixteenths thick, with a white vesicular nucleus. These were the most numerous.

2. Ellipsoidal and spheroidal stones, about the same length, many of them hollow shells.

3. Smaller angular and irregular pieces, mostly opaque (apparently from the presence of numerous air bubbles): one of these (a fairly large one) showed three layers, the middle one transparent, the upper and under ones white and opaque.

"The Cold Period from September 1887 to May 1888." By Charles Harding, F.R.Met.Soc. (p. 270.)

"Observations on Cloud Movements near the Equator, and on the General Character of the Weather in the Doldrums." By the Hon. Ralph Abercromby, F.R.Met.Soc. (p. 281.)

THE ERUPTION OF KRAKATOA AND SUBSEQUENT PHENOMENA.

THE Report of the Committee appointed by the Council of the Royal Society on January 17th, 1884, "to collect the various accounts of the volcanic eruption at Krakatoa, and attendant phenomena, in such form as shall best provide for their preservation and promote their usefulness," has just been published. It is a volume of 510 pages (royal 4to), with 45 coloured and other Plates.

The work is divided into four Parts, viz. :—

I. On the Volcanic Phenomena of the Eruption, and on the nature and distribution of the ejected materials; by Prof. J. W. Judd, F.R.S.

II. On the Air Waves and Sounds caused by the eruption; by Lieut.-Gen. R. Strachey, F.R.S. This part shows that the concussion to the atmosphere was so intense that it affected every barometer in the world, and set up a series of air waves which were traceable more than four days after the eruption, and that the sound was heard fully 2,000 miles from Krakatoa.

III. On the Seismic Sea Waves caused by the eruption; by Capt. W. J. L. Wharton, F.R.S. This describes the fearful loss of life and damage produced by the great wave 135 feet high, and the rate of translation of that wave to all the principal tide-gauges in the world.

IV. On the unusual Optical Phenomena of the Atmosphere 1883-86, including Twilight effects, Coronal appearances, Sky Haze, Coloured Suns, Moons, &c.; by the Hon. F. A. Rollo Russell, M.A., and E. D. Archibald, M.A.

V. On the Magnetical and Electrical Phenomena accompanying the Krakatoa explosion; by G. M. Whipple, B.Sc.

The whole work has been edited by Mr. G. J. Symons, F.R.S., Chairman of the Committee.

As the members of the Committee appointed by the Council of the Royal Meteorological Society on January 16th, 1884, to investigate the cause of the remarkable sunrises and sunsets,[1] were subsequently incorporated in the Krakatoa Committee of the Royal Society, we give *in extenso* the conclusions and summaries of Messrs. Archibald and Russell on the unusual Optical Phenomena of the Atmosphere 1883-86.

Summary of evidence respecting the particles of Dust.

Mr. RUSSELL says :—We may probably conclude that the haze which followed the eruption of Krakatoa, and produced the twilight glows, was composed mainly of very fine dust; and that this dust at a great altitude reflected the light of the setting or rising sun after diffraction through the dust stratum and subsequent diffraction and absorption by the lower atmosphere. This reflected light becoming secondarily reflected.

The remarks on this section are summarised as follows :—

1. The fall of dust, chiefly pumiceous, at great distances from Krakatoa westward, on the days following the first appearance of the red twilight.
2. The existence of a white haze at a great altitude during their prevalence.
3. The great effect produced by small vitreous surfaces in reflecting sunlight when the intervening air is darkened.
4. The failure of the spectroscope on the whole to indicate an increased strength in the lines due to vapour.
5. The structure of the haze, more resembling that of smoke than that of the highest clouds.
6. The resemblances and contrasts between reflection of sunset rays from thin high clouds and from the haze-stratum, both in the first and the second after-glows.

[1] *Quarterly Journal*, Vol. XI. p. 75.

7. The sequence of colours, corresponding with what might be expected to be the changes of colour due to the sinking or rising sun at the altitude of the stratum.

8. Previous effects seen in years of great eruptions, especially 1831, and in places affected by an excess of dust in air.

9. The extreme lightness of pumice dust and the theoretical floating power of fine particles.

The Blue, Green, and other Coloured Appearances of the Sun and Moon.

Mr. ARCHIBALD summarises this section as follows:—

1. That the appearances of blue, green, silvery and coppery sun, seen mainly in the tropical zone after the eruption of Krakatoa on August 27th, and sporadically after its predecessor in May 1883, were produced by the action of a haze which proceeded from the neighbourhood of the volcano, and were composed either of dust and vapours mixed, or of dust alone, probably the former at first.

2. That the silvery or pale sun was seen where the haze was most dense near the parallel through Krakatoa.

3. That the coppery sun was seen either near the Equator, or where a narrow shoot of the stream occurred towards Japan, and near the eruption as at Teloek Betoeng, from which it may be inferred to have been caused by dense, and perhaps coarse, dust from the eruption, mingled with lower atmospheric absorbing agents.

4. That the blue and green suns were seen further from the latitude of Krakatoa and the Equator, where the stratum was more attenuated.

5. That where the sun was seen blue near the zenith, it frequently became green or yellow on approaching the horizon, and *vice versâ*, and that these changes of tint were due to changes in the thickness of the medium and of the lower atmosphere traversed.

6. That similar appearances have been witnessed on former occasions in association with accompanying volcanic phenomena, and in regions where the air was, during the time, charged with terrestrial dust.

7. That Professor Kiessling, of Hamburg, has experimentally obtained a blue sun—(1) with a cloud of chloride of ammonium, and (2) with aqueous vapour mixed with ordinary dusty air.

8. That while in the tropical zone the coloured suns occurred for the first month after the eruption co-extensively with the other optical effects, the sun and moon were only occasionally and temporarily seen green at a few places in the extra-tropics; and in some of these it is not certain that the appearances were due to anything more than contrast colours.

The Sky-Haze and some of its Effects.

Mr. ARCHIBALD gives the following conclusions with regard to the cloud-haze:—

1. That soon after the grand eruptions of Krakatoa on August 26th and 27th, a remarkable dimming of the sun took place in the immediate neighbourhood of the volcano, together with haze and falls of dust on ships, which in one case (the *Scotia*, September 8th, in lat. 10° N, long. 53° E, "still a deposit of sand found") extended no less than 52° to the westward, and more than 3,700 English miles from the volcano.

2. That this haze was propagated mainly westwards, concurrently with the other optical phenomena, from the neighbourhood of Java.

3. That most observers agree in considering it to be the proximate cause of the other optical effects, including the twilight glows, coloured suns, and large corona.

4. That it was densest in the Indian Ocean and along the equatorial belt, where it was often thick enough to hide the sun entirely when within a few degrees of the horizon, besides sensibly colouring its rays when at greater altitudes. In the extra-tropics it was much less dense, and was generally visible only at sunrise and sunset; though even there it peculiarly affected astronomical definition in a manner different from ordinary aqueous haze.

5. That while, in some of its features, it partook somewhat of the character of

a lofty cirrus or cirro-stratus cloud, it yet differed in many respects from an ordinary aqueous cirrus.

6. That it appeared to be far above ordinary cirri, and exhibited an absence of the curls and twists by which such clouds are usually characterised, and which are usually attributed to local atmospheric movements at their level.

7. That while it was at a height where the temperature is always far below the freezing-point of water, no trace of true ice-halos was observed, and that while it produced some effects, such as coloured suns and glows, which might, in certain circumstances, have been caused by aqueous vapour, the general evidence shows that it contained something besides ordinary aqueous vapour, and that it was either entirely fine dust or a mixture of frozen vapour of water or other substances with dust.

8. That the spectroscopic evidence tends to show that the haze was not gas, but a cloud of solid particles, either ice or dust, which at first cut off the red end of the spectrum relatively more than the violet, and subsequently exercised a general absorption, which was more noticeable in the less intense rays at each end than towards the middle.

9. That it had appeared on former occasions (1783 and 1831) in association with pale suns and twilight glows, which were at that time ascribed to contemporaneous eruptions.

The large Corona round the Sun and Moon in 1883-4-5, generally known as "Bishop's Ring."

Taking all the facts regarding the corona, or Bishop's Ring, together, Mr. ARCHIBALD arrives at the following conclusions :—

1. That the date on which it was first distinctly seen was September 5th, 1883, by Mr. Bishop, at Honolulu, after which it appeared at most places where the other optical effects were witnessed.

2. That its principal colours were bluish-white in the centre, shading off into a reddish-brown border, the diameter of the inner space being about 21°, and the entire ring, to the external boundary of the red, about 45° 30′. Round the moon the only colour distinguishable was a pale reddish circular boundary, the apparent diameter of which was somewhat smaller than that round the sun.

3. That when it was visible it appeared all day from sunrise to sunset under favourable conditions.

4. That it reached its maximum intensity about the Spring of 1884, since which time it gradually declined in brilliancy and visibility down to June 1886. Since this latter date it has not been seen even by a most careful observer, Professor Riccò.

5. That it was best seen at great altitudes ; and near the earth it was best seen on days when the air was free from ordinary dust or smoke.

6. That it appeared to be independent of all ordinary atmospheric disturbances.

7. That it was most probably formed in the haze stratum, which proximately caused the twilight glows and other optical phenomena.

8. That though a white glare, resembling its inner portion, had been observed in previous years by Professor von Bezold, he had never before seen a corona of the same size and with the marked reddish border.

9. That it was a diffraction corona produced by the accompanying haze, and that its great size proves this haze to have been composed of exceedingly small particles.

10. That the order of the colours shows it to have been most probably a diffraction ring of the first order.

11. That the occurrence of a corona in so elevated a region, as well as the general absence of accompanying refraction halos, tends to show that the particles through which the diffraction took place were solids, and dust rather than ice.

12. That while the corona was associated with the twilight glows and coloured suns in being produced by the same elevated haze, it was physically distinct from either, and probably contributed only very slightly to the glows, after the sun sank below the horizon.

13. That, from Dr. Kiessling's experiments, it appears that exactly similar phenomena can be produced on a small scale by diffraction of the sun's rays through minute dust, or vapour momentarily condensed in ordinary dusty air.

General Geographical Distribution of all the Optical Phenomena in Space and Time.

Mr. RUSSELL says :—The dates in the general list leave no doubt that, on the whole, the tendency of the matter causing the twilight phenomena was to spread northwards and southwards as well as westwards during the rapid circuit of the blue sun matter from east to west within the tropics. The dates for India and the United States show this most distinctly. Excluding sporadic glows, due probably to small broken off masses of the great cloud of matter, we find the northern limit near the end of the first circuit to have been about 22° N at Honolulu, or 28° north of Krakatoa, and the southern limit about 33° S at Santiago, or 27° south of Krakatoa. Wellington, New Zealand, at 41° S, cannot be taken as the southern limit; for Australia does not seem to have been affected so early as September 9th. In none of those places which were on the extreme borders of the main stream, or beyond it, were the glows regular and continuous from the date of the first appearance. Nor could they be expected to show continuity, when we have evidence that the cloud causing the rayless sun passed over most places in the tropics within three or four days. Towards the end of the first circuit, that is, in the Pacific, the amount of matter left behind after the passage of the main cloud seems to have been greater than in the Atlantic near the Equator, where the sky in most parts presented no remarkable appearance after September 5th until the arrival of the cloud on its second circuit.

At the end of the second circuit, about September 22nd, the glows may be roughly stated to have extended from between 20° and 30° N to between 30° and 40° S, but their distribution was not regular within these limits.

While the movement westwards may be presumed to have continued after this date, there can be no doubt that a gradual extension northwards and southwards greatly widened the area over which the red twilights were seen during the next fortnight. They were conspicuous at several places between 20° and 36° N, and southwards as far as 27° S, in many different longitudes. Throughout October the Gulf of Mexico and corresponding latitudes were under the full effect of the glows. On October 7th, Nashville, about 36° N, and Buenos Ayres, at 34° 39′ S, had brilliant sunsets; and at Binninag, India, 29° 30′ N, 80° E, there was a fiery after-glow till 7.20 p.m. At the Canary Isles, 28° N, the glows were conspicuous. At Shanghai, or not far south of it, they were observed by pilots.

By October 15th the glows had extended still further north; in the United States they had reached 34° 27′ N, in Europe partially to 43° 42′ N, in Arabia to an unknown latitude, and in India to Umballa 30° N.

By the end of October the glows had spread over the southern and part of the eastern States of North America, while Australia, Tasmania, New Zealand, South Africa, and Chili, were under their full effect.

Up to about November 23rd, glows seen north of about 32° to 36° N were for the most part detached or sporadic.

But about November 23rd a very remarkable movement took place in such a manner that the direction in which the main stratum progressed is not clear, in spite of a large collection of dates. Western Canada, British Columbia, California, and north-west Iceland, seem to have been first affected, and then in succession England, Denmark, France, Italy, Germany, Spain, Algeria, Austria, Turkey, Russia, eastern Siberia, and northern China. To distinguish sporadic from continuous glows is no easy matter. But a general view inclines us to regard this latter movement as taking place from west to east. An exact course cannot be determined, owing to the inequality in density and irregularity of outline of the great cloud. Excluding occasional displays, the glows were seen in the north-western parts of Europe about a week before they drew attention in the east and south-east. England, as a whole, was affected before Denmark as a whole, Denmark before northern Russia, northern Russia before Kiachta. North Italy and Lisbon, parts of France and Germany were affected on the 26th, south-east Iceland and a large part of western and central Europe on the 27th, part of eastern Europe on the 28th, southern Italy and Greece about December 1st.

Over the northern part of North America the direction of movement does not appear, for the glows were seen about November 23rd in both east and west, and we can only infer that they were spreading quickly from the south, where they had long been sporadically noticed. San Francisco, New Westminster, and Oregon and London, Ontario, report them as beginning about the same time. On November 27th they were general in the States.

Perhaps the most probable supposition is that the main cloud both in America and in Europe was moving from nearly west to east, at all events in the northern parts, with large offshoots extending from south or south-west to north or north-east. On the assumption of the northern limit having been continuous in the same latitude, it would be difficult to account for the eastern States having had glows at the same time as the western (while in Europe the east was later by about a week), and for England having been the first of European countries to enjoy them in their full splendour.

The movement of the earlier detached clouds, which reached parts of the northern States, England, and Russia, between November 8th and 11th, is equally uncertain. Their structure in England, however, indicated a movement from a point between W and S.

The structure of the main cloud indicated a motion from SSW to NNE, or an initial motion from south to north, gaining an eastward drift. Observation showed, if anything, a slow motion from west to east.

A survey of the course of the phenomena of the sunset glows leads us to infer that within the tropics the matter causing them moved at about 73 miles an hour from east to west, and gradually spread southwards and northwards, becoming thinner and more diffused, so that by the end of a period of six weeks, viz. the 8th of October, nearly the whole space included between 30° N and 45° S had been subject to the phenomena; and that the motion from east to west became arrested as the matter travelled northwards and southwards. Further north and south than about 30° or 35°, it seems probable that the motion was from south-west and west in the northern hemisphere, and from north-west and west in the southern hemisphere. The rapidity of propagation to South Africa and Japan was so great that we can hardly doubt the prevalence at the time of a direct upper current in each direction at a level below that of the great current which carried the dust from east to west at the velocity above mentioned. The march of the glows over North America and Europe at the end of November appears to have been part of a movement of the hazy stratum from over the mid-Pacific and mid-Atlantic Oceans respectively, but we have no data for affirming that the glows receded from those vast areas at the corresponding time. From Honolulu we have a report of an increase in brilliancy on November 25th, and of a prevalence of the glow between Honolulu and New Hanover continuously during September, October, and November; while the *Papa*, sailing from Apia (Samoan Islands), had nothing of the kind during October and November.

Diurnal and Secular Variation in the Duration and Brilliancy of the Twilight Glows, and the Height above the Earth of the Stratum which caused them.

Mr. ARCHIBALD summarises this section as follows:—

1. That in the brilliant glows which began in the tropics after the eruption of Krakatoa on August 26th and 27th there is distinct evidence of a primary glow caused by the direct rays of the sun, and of a secondary glow succeeding this, and due to reflection of the primary glow by the same stratum. That these primary and secondary glows correspond to the first and second crepuscular spaces of ordinary twilight; and that the main difference between the secondary of the present series and the ordinary second crepuscular space is that the former was coloured, whereas the ordinary second twilight is white, and seen only from high altitudes or in peculiarly favourable circumstances.

2. That the glow-causing material appeared suddenly and at about its greatest height, at first in the Indian Ocean, near Krakatoa, and for some degrees north and south of its parallel throughout the tropical zone; that it subsequently spread into the extra-tropics; and that, partly owing to lapse of time and partly to change of locality, it appeared at a lessened altitude.

3. That the height of the upper or middle part of the stratum, as deduced mainly from the particles which were large enough to reflect, progressively

diminished from 121,000 feet in August to about 64,000 feet in January 1884, the inferior limits being more probably from 104,000 feet in August to 56,000 feet in January, and the corresponding means, 87,500 feet from the longer durations and 70,000 feet from the mean durations respectively.

4. That by April 1884 a considerable portion of the larger reflecting particles had been sifted out by gravitation, causing a minimum duration and brilliancy of the secondary glow; that as this occurred coincidentally with a maximum development of the corona, or Bishop's Ring, we are led to conclude that a large portion of the finer material remained in suspension at nearly the same height as at first, and that having become more homogeneous than at first, it was rendered capable of exerting its maximum diffractive power.

5. That while the present series of glows, both primary and secondary, reached a decided minimum everywhere about April 1884, they subsequently exhibited a partial renewal of their former brilliancy and duration in the autumn and winter months of 1884 and 1885, similar to what is found to occur normally at such seasons through the influence of certain meteorological factors in the ordinary twilights—a fact which renders it impossible to arrive at any certain deductions regarding the rate of descent of the stratum as a whole.

6. That the brilliancy and duration of the phenomena were closely connected, but how far the duration was dependent on, or independent of, the precise quality or brilliancy of the glow, does not exactly appear; of the two glows. the secondary seems to have far exceeded the primary in the amplitude of its variations and its sensitiveness to general meteorological influences.

7. That the rapid decline of the glows both in brilliancy and in duration in the spring of 1884, and their subsequent re-appearances in the latter parts of 1884 and 1885 with a much reduced brilliancy, show that, while they were caused by the presence of an unusual quantity of dust in the upper regions of the atmosphere, this material gradually became eliminated, until, by the commencement of 1886, things had returned to their normal condition.

8. That while the duration of twilight was sensibly lengthened during the prevalence of the glows, the action of the glow-causing materials, except in as far as it tended to transmit the blue rather than the red end of the spectrum (partly by diffraction and partly by absorption), and thus produce certain unusual tints and sequences of colour, affected the sun's light in a manner somewhat similar to that produced by the dust and vapour particles ordinarily present in the atmosphere at lower elevations. That the final effects were produced by the prolonged reflection from the lofty stratum of rays—(1) partly deprived of their red components by the action of the stratum itself, and (2) to a much larger extent subsequently deprived of their blue components by the ordinary dust and vapour particles of the lower atmosphere. It was, therefore, mainly an intensification of ordinary twilight phenomena, consequent on the presence, at a lofty altitude, of solid particles not usually existent there.

9. That similar unusually brilliant and long twilight glows, including the secondary coloured glow, which is one of the principal characteristics by which the present series has been distinguishable from ordinary twilight phenomena, have been witnessed at intervals in former years, and generally in association with volcanic phenomena.

General Analysis of the Connection between the unusual Meteorological Phenomena of 1883-6 and the Eruptions of Krakatoa in May and August 1883.

Mr. ARCHIBALD says:—We shall conclude by summarising as briefly as possible the chief reasons for considering all the unusual optical effects (including those seen in extra-tropical latitudes) which made their appearance in September, October, November, and December, 1883, and in part thenceforward up to the end of 1885, to be direct consequences of the eruption of Krakatoa in August 1883.

1. The fact that the entire range of optical effects including the brilliant and unusually prolonged glows at sunrise and sunset, the blue, green, silvery and coppery appearance of the sun, the lofty cloud-haze, and the large corona round the sun and moon, made their appearance locally after the minor, and universally after the major, eruptions in such a manner as to show that they all had a common

origin both in space and in time, and that this origin was the neighbourhood of the volcano Krakatoa in May and August 1883.

2. That the twilight glows, coloured sun, cloud-haze, and corona (the latter being less frequently observed at first, though not less widely spread than the other), appeared for the most part progressively along and symmetrically with respect to, a line extending west from Java and parallel with the Equator, the motion along this line being evidently real, since they are shown to have appeared at places where they had not previously been seen, or to have re-appeared where they had temporarily declined, after they had made one complete circuit of the globe, and at substantially the same rate in longitude as at first.

3. The unusual character, duration, and universality of the cloud-haze, its effect on astronomical definition, its general similarity to attenuated volcanic smoke or dust, and the general testimony in favour of the fact that this haze was the proximate cause of all the other optical phenomena.

4. The unusual character, duration, and large size of the coronal appendage to the sun, showing that the haze which caused it was composed of very small particles, its independence of all ordinary meteorological changes, its survival of the glows, and the gradual disappearance of both haze and corona in the summer of 1886.

5. The extraordinary height to which the ejecta of the eruption of Krakatoa, on August 26th, were observed to ascend, and the fairly close agreement of this and other direct observations with the height of the stratum as calculated from the duration of the twilight glows in the tropics and in the neighbourhood of the volcano. Also the fact that the greatest mean height of the stratum was observed at first in the tropical and Indian area, and that as time went on a gradual subsidence of the material took place everywhere, as would be likely to occur if it were dust ejected from below into the upper regions.

6. The evidence given already on "Previous analogous Glow Phenomena," which in many cases are shown to be directly consequent on eruptions of neighbouring or distant volcanoes; as also the phenomena observed by Whymper in the Andes, and certain effects noticed in the vicinity during the eruption of Krakatoa, and recorded in Mr. Verbeek's *Krakatau*.

There are many minor considerations which point the same way, and which have been incidentally mentioned or implied in the foregoing sections. Amongst others, the continuity of the propagation of the material and the corresponding optical phenomena, from their first general appearance in the Indian Ocean, after August 26th, including their successive revolutions round the globe from east to west, within the tropics, and their subsequent spread from west to east over northern Europe and Asia. Also the fact that while Bishop's Ring appeared sporadically in a few places after the May eruptions of Krakatoa, it seems never to have been observed by such careful observers as Professor von Bezold, M. Thollon, of Nice, and Mr. T. W. Backhouse, of Sunderland (a halo observer for 25 years), until the general arrival at their respective localities of the haze and other optical phenomena which succeeded the August eruptions. There are one or two minor points which present opportunities for further research; for example, the precise effects of dust, or dust and vapour, upon sunlight. Professor Tyndall's, Professor Kiessling's, and Captain Abney's experiments on the dispersion and diffraction of light by small particles, have advanced the question individually, but much remains to be done. Amongst others, further information would be desirable on the following points:—

(1). The inferior limit of the size of ice particles produced from vapour.

(2). Observations as to the rate of fall of small particles in rarefied air.

(3). The duration of ordinary coloured twilights under different meteorological conditions.

(4.) The motion of the upper cloud systems near the Equator.

(5.) The meteorological and physical conditions under which ice crystals would produce diffraction coronæ and not refraction halos.

CORRESPONDENCE AND NOTES.

Freezing of the Boden See, or Lake of Constance.

The Assistant Secretary, Royal Meteorological Society.

Dear Sir,

I send you as desired the list I copied from the Barometer Stone stand, on the sides of which the dates and figures are inscribed, in the Public Promenade at Constance.

Boden See Zugefroren.

1076	1325	1497	1684	1830
1108	1379	1565	1695	1880
1277	1435	1573	1788	

The height above mean sea level is 400 metres (1,312 feet). Constance is in 47° 39′ N. lat. and 9° 10′ E. long., and the means of its winter months are

1°·0 C. (33°·8 F.) in December and January.
1°·7 C. (35°·1 F.) in February.

This list is not in favour of the theory of the winters growing milder, rather the contrary.

Yours faithfully,
Simpson Rostron.

Beddington, Surrey.
Oct. 1st, 1888.

RECENT PUBLICATIONS.

American Meteorological Journal. A Monthly Review of Meteorology, Climatology and Geography. Vol. V. Nos. 3-5. July-September 1888. 8vo.

The principal original articles are :—A new Wind Vane, by W. A. Glassford (3 pp.).—The new Swiss Meteorological Observatory on the Sentis (8,200 feet), by A. L. Rotch (6 pp.).—Comparison of Standard Barometers, by F. Waldo (8 pp.).—South Alberta, and the Climatic Effects of the Chinook Wind, by C. C. McCaul (14 pp.).—Prof. Cleveland Abbe, of Washington (10 pp. and portrait). This is an interesting sketch of the life and labours of the celebrated American meteorologist.—The Organisation of the Meteorological Service in some of the principal countries of Europe, by A. L. Rotch (8 pp.). The author in this paper gives an account of the meteorological service in Switzerland.—Suction Anemometers, by G. E. Curtis (16 pp.).—Indian Cyclone of October 1864, by Mrs. J. N. Brodhead (5 pp.).—Mount Washington as a Meteorological Station, by H. A. Hazen (4 pp.).

Annuaire de la Société Météorologique de France. 36me Année. March-June 1888. 4to.

Contains :—Note sur un anémomètre à enregistreur électrique, par P. Garrigou-Lagrange (2 pp.).—Remarques théoriques sur les mouvements gyratoires de l'atmosphère, par H. Lasne (6 pp.).—Mesure des hauteurs et des mouvements des nuages au Spitzberg et à Upsala, par N. Ekholm (12 pp.).

BULLETIN ANNUEL DE LA COMMISSION MÉTÉOROLOGIQUE DU DÉPARTEMENT DES BOUCHES-DU-RHONE. Publié sous les auspices du Conseil Général. Année 1886. Vol. V. 4to. 1887. 186 pp. and 8 plates.

This organisation comprises a staff of 36 observers. The observations made at the Marseilles Observatory six times a day are printed in full. In addition to other information the present volume contains the following memoirs :—Documents relatifs au climat de Marseille. This includes tables of mean and extreme temperatures and rainfall for the 64 years 1823-86.—Note sur le tremblement de terre du 23 Février 1887 à Marseille et dans le Département des Bouches-du-Rhône.—La période pluvieuse du 11 Septembre au 12 Novembre 1886, et l'inondation des mines de Fuveau.—Relations entre les pluies et le régime des eaux souterraines dans la concession de Trets.—Influence de l'état atmosphérique sur la santé publique à Marseille pendant l'année 1886.

CIEL ET TERRE. Revue populaire d'Astronomie, de Météorologie, et de Physique du Globe. Deuxième série, 4me année, Nos. 11-16. 8vo. 1888.

The principal meteorological articles are:—Etude de la structure de l'éclair par la photographie, par W. Prinz (7 pp. and plate).—Les climats anciens (3 pp.).—Revue climatologique mensuelle, par A. Lancaster.

FIFTEENTH ANNUAL REPORT OF THE SECRETARY OF THE STATE BOARD OF HEALTH OF THE STATE OF MICHIGAN for the Fiscal Year ending June 30th, 1887. 8vo. 1888. 282 pp.

This contains a paper by Dr. H. B. Baker entitled "The Causation of Cold-weather Diseases," which is an attempt to explain the causation of inflammations of the air-passages, and the seasonal susceptibility to certain communicable diseases which are shown to be most prevalent in cold weather.

INSTRUCTIONS FOR OBSERVING CLOUDS ON LAND AND SEA, with Photographs and Engravings. By Hon. RALPH ABERCROMBY, F.R.Met.Soc. 8vo. 22 pp. 1888.

The author states that the three things to be observed relative to clouds are :—(1) the form ; (2) the trend or bearing of certain linear forms ; and (3) the direction of motion at various levels. Full directions are given for making these observations. The nomenclature used is that proposed by Prof. Hildebrandsson and Mr. Abercromby for international use (See *Quarterly Journal*, Vol. XIII. p. 154). The reproductions of ten photographs of cloud forms are very good.

METEOROLOGISCHE ZEITSCHRIFT. Herausgegeben von der oesterreichischen Gesellschaft für Meteorologie und der deutschen meteorologischen Gesellschaft. Redigirt von Dr. J. HANN und Dr. W. KÖPPEN. July-September 1888. 4to.

The chief articles are:—Resultate der meteorologischen Beobachtungen der deutschen Polarstationen 1882–83, besprochen von Prof. E. Brückner (15 pp.).—Zur Frage der Herleitung wahrer Tagesmittel der Lufttemperatur aus drei-resp. viermaligen Beobachtungen, von Dr. P. Schreiber (10 pp.). This is a comparison of the results yielded by the combination of observations taken at 6 a.m , 2 p.m., and 10 p.m.; 7 a.m., 2 p.m., and 9 p.m.; and 8 a.m., 2 p.m., and 8 p.m. respectively, with true 24 hours means. The author says that all require a correction depending on the amplitude of diurnal range, that this is greatest and also most variable with 8 a.m., 2 p.m. and 8 p.m., while with 7 a.m., 2 p.m., and 9 p.m., and especially with 6 a.m., 2 p.m., and 10 p.m., the mean value of this correction can be taken for a month at a time.—Ueber die Scintillation, von Prof. K. Exner (11 pp.).—Mittlere Windgeschwindigkeiten in den Vereinigten Staaten, von F. Waldo (12 pp. and 3 plates). This is a comparison of the mean velocity of the wind for each month for some 70 anemometrical stations in the United States.

The instruments are apparently all exposed on roofs, but the altitudes above the ground vary from 10 feet at Behring's Island to 208 feet at St. Louis, so that there is a wide range in this particular. The greatest velocity is at Pike's Peak, 25·3 miles per hour in February and March. At most stations the maximum occurs in March.—Ueber die Einfluss der Sonnenstrahlung auf die elektrischen Erscheinungen in der Erdatmosphäre, von S. Arrhenius (20 pp.). The author comes to the conclusion that the electricity is much greater with a clear than with a cloudy sky; that the electricity has no obvious connection with relative humidity, or with vapour tension, but that it is closely related to thunderstorms. There is a close relation between electricity and actinometric observations; and the author assumes that the sun is the most active factor in conveying the negative electricity of the earth to the clouds.—Ueber die Bewegungserscheinungen der Atmosphäre, von Prof. A. Oberbeck (5 pp.).—Ueber atmosphärische Bewegungen, von H. von Helmholtz (12 pp.).—Ueber die jährliche Schwankung des Barometers in Indien, von S. A. Hill (8 pp.). The author "Besselizes" the means for 24 stations distributed over India, from Yarkand to Colombo. The means are mostly for 12 years, and he points out various features which, as yet, have not been noticed in Europe.

PROCEEDINGS OF THE PHYSICAL SOCIETY OF LONDON. Vol. IX. Part 8. July 1888. 8vo.

Contains:—Observations on the height, length, and velocity of ocean waves, by Hon. R. Abercromby (7 pp.). Several sets of observations between New Zealand and Cape Horn, with an aneroid barometer, gave for the largest waves a height of 46 feet, a length of 765 feet, a speed of 47 miles an hour, and a time period of 16·5 seconds. As nothing but the ordinary heavy weather of these latitudes was experienced, it is certain that waves must sometimes attain a height of at least 60 feet.

PROCEEDINGS OF THE ROYAL SOCIETY. Vol. XLIV. No. 270. 8vo. 1888.

Contains a paper by Mr. R. Abercromby "on Meldrum's Rules for handling Ships in the Southern Indian Ocean" (3 pp.). The author examines critically certain rules given by Mr. C. Meldrum for handling ships during hurricanes in the South Indian Oceans, by means both of published observations and from personal inspection of many unpublished records in the Observatory at Mauritius. The result confirms the value of Mr. Meldrum's rules; and the author then develops certain explanations, which have been partially given by Meldrum, adds slightly to the rules for handling ships, and correlates the whole with the modern methods of meteorology. From all the facts relative to the nature of cyclones adduced in this paper it is shown that the attempts which have been made:—1. To estimate the track of a cyclone by projection. 2. To estimate the distance of a ship from the vortex, either by taking into account the entire absolute fall, or by noting the rate of fall, can lead to no useful result. A series of revised rules for handling ships in hurricanes in any part of the world is given. Comparing these rules with the older ones it will be remarked:—1. That the rule for finding approximately the bearing of the vortex is slightly modified. 2. That the great rules of the "laying to" tacks remain unaltered. 3. That the greatest improvement is the recognition of the position and nature of the belt of intensified Trade wind on the dangerous side of a hurricane, where a ship experiences increasing wind without change of direction and a falling barometer. The old idea that such conditions show that a vessel is then necessarily exactly on the line of advance of a hurricane is erroneous. She may, but she need not be so; and under no circumstances should she run till the barometer has fallen at least 6-10ths of an inch. 4. There are certain rules which hold for all hurricanes; but every district has a special series, due to its own local peculiarities. Those for the Southern Indian Ocean are given in this paper.

QUARTERLY RECORD OF THE ROYAL BOTANIC SOCIETY OF LONDON. Vol. III. No. 34. June 1888. 8vo.

This contains a most interesting and instructive Lecture on "Sunshine," by Mr. G. J. Symons, F.R.S., delivered at the Royal Botanic Society on May 29th.

The author gives "to the best of his knowledge and belief" a history of the various methods which have been adopted of registering the intensity of the solar rays and the amount of sunshine. The instruments employed are fully described and illustrated. In the latter part of the lecture reference is made to the action of light upon vegetation.

REPERTORIUM FÜR METEOROLOGIE. Herausgegeben von der Kaiserlichen Akademie der Wissenchaften. Redigirt von Dr. H. WILD. Band XI. 4to. 1888.

This volume contains 14 long and 5 short papers, among which are the following:—Die mittlere Vertheilung des Luftdrucks im europäischen Russland von 1881-1885; von B. Sresnewsky (70 pp. and 3 charts). This is based on the observations of 53 stations. The mean varies from 30·06 ins. at Astrachan to 29·85 ins. at Archangel.— Die Vertheilung der Winde und des Luftdrucks über dem Kaspischen Meer; von M. Rykatschew (97 pp. and 6 charts).—Untersuchungen über die Leistungsfähigkeit eines Richard'schen Thermographen (41 pp. and 2 plates). This was carefully compared with a Hasler's thermograph, and with a mercurial thermometer. The results were very satisfactory, but it is recommended to make both clock and paper run only for three days instead of a week, and thus open the scale and correct the error of the clock.—Zur Frage über die Vorausbestimmung des Temperaturminimums; von B. Kiersnowsky (16 pp.). This is to test Kammermann's rule (See *Quarterly Journal*, p. 248). The author finds that nothing can be obtained from the dew point, but says that the difference between the wet-bulb reading at 1 p.m. and the minimum at night is fairly constant, ranging from 4°·2 to 1°·4 C., and that the reading at 9 p.m. gives a less difference and is more constant, so that the last is the best to take.—Vergleichende Verification zweier Anemometer in Hamburg und in St. Petersburg; von W. Dubinsky (16 pp.). This is a comparison of the results of testing two small anemometers on the Combe's apparatus at Hamburg and St. Petersburg. The results agree well, and the author pleads that the mode of determining the "*Mitwind*" is now quite satisfactory.—Ueber die Berechnungsweise und die Zulässigkeit der Luftdruck-Mittel aus Aneroid-Beobachtungen; von A. Schoenrock (16 pp.). The result of this paper is to show that if aneroids have been twice compared at the stations the intermediate readings can be used. If three comparisons exist, the correction may be applied to readings before the first comparison. Comparisons at a central office are of little use, owing to change of correction in transport. Aneroids are decidedly less sensitive than mercurial barometers.—Beitrag zum Studium der Gewitter Russlands; von A. Schoenrock (18 pp. and plate). This is a discussion of four special storms. The author points out one or two curious facts: one that thunderstorms avoid lakes, and are said never to cross them; the other that the spots most visited are not those where these storms most frequently take their rise.—Die Bedeutung der absoluten Feuchtigkeit für die Entstehung und Fortpflanzung der Gewitter; von E. Berg (19 pp. and plate). This paper goes to prove that vapour tension is the element which principally decides the origin and march of thunderstorms.

SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. Vol. XXIII. Nos. 271-273. August-October 1888. 8vo.

The principal articles are:—Rainfall of Spain and Portugal (5 pp.).—Exceptional Phenomena in July 1888 (5 pp.).—On July 1888 in Norway, and on Weather Zones in Northern Europe (3 pp.).—The rain and thunderstorms of July and August 1888 (6 pp.). On July 31st, 3·40 ins. of rain fell in the neighbourhood of Hastings, and on August 1st, more than 4·50 ins. fell near Romford in Essex.—Are thunderstorms more frequent in towns than in the open country? by C. Tomlinson, F.R.S. (1 p.).—The British Association at Bath (7 pp.).

THE FLOWERING PLANTS OF WILTS. With Sketches of the Physical Geography and Climate of the County. By the Rev. T. A. PRESTON, M.A., with a Map. 8vo. 505 pp. 1888.

The introduction to this book contains interesting articles on—1. Topography, by Rev. J. Sowerby; 2. Geological features; 3. Drainage, by G. S. Boulger;

4. Climate; 5. Botanical districts; and 6. Plan of the Flora. In section 4 Mr. Preston compares the climate of Marlborough, as being typical of the Down country, with that of the rest of England, and then with that of Salisbury. The author says "that the climate of Marlborough is approximately continental: and (considering the small size of England) its temperature in summer is great, its cold of winter almost excessive. Its sunshine is plentiful, its rainfall moderate. Its spring is decidedly cold, and the keen East winds which sweep over the Downs render it a trying spot for persons with weak lungs; but, on the other hand, its singularly pure atmosphere is very invigorating, and if a person with a weak chest can only manage to pass one winter there, he soon becomes acclimatised and (as has been proved by experience with delicate boys) grows up into a strong healthy man."

TRANSACTIONS OF THE HERTFORDSHIRE NATURAL HISTORY SOCIETY. Vol. V. Part 1. August 1888. 8vo.

Contains:—A record of water level in a deep chalk well at Barley, Herts, 1864-86, by H. G. Fordham (3 pp. and plate). This well is sunk in the middle chalk, and the depth is 165 feet from the top ground surface, which is 305 feet above sea level. Taken generally, the movement of the water is a rise for five months (November to March), and a fall for the remaining seven months, through the summer and autumn. Great variations occurred from the mean level in years of, and those following, excessive and small rainfalls. The greatest variation in one year was 37 feet in 1869, and the least, 12 feet in 1871.

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